MANAGING TREES TO REDUCE DAMAGE FROM LOW-LEVEL SALINE IRRIGATION

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Accumulation of salts in shade trees from low-level saline irrigation water (which is absorbed by the roots and left behind in the leaves from evaporation and transpiration) is common in areas where irrigation is used to supplement the natural rainfall. It is more common where most of the water taken up by the trees is from irrigation. Chloride builds up in the leaves where the water contains 40 ppm chloride. This is common in Bryan-College Station, Texas, and in areas to the west and north. Calcium and sulfate in the water tend to reduce the amount of damage from the sodium and chloride.

The damage to vegetation from low levels of salt is occurring with water usually considered safe for irrigation. The water in Bryan and College Station is classed as fresh or slightly saline (Texas Dept. Health 1977, Winslow and Kister 1956), but evaporation from the leaves causes chloride to build up in them to well above toxic levels. The sodium also builds up to high levels in the soils. The soils themselves contribute to the problem because their impermeability prevents the salts from being leached away, and the abundant montmorillonite clay has a great capacity to absorb sodium.

The salinity standards for waters have been set by their content of total dissolved solids (Winslow and Kister 1956), but the water in Bryan, College Station, and Texas A&M University has an uncommonly high proportion of its dissolved solids in sodium and chloride (Tex. Dept. Health 1977). Carbonate is the only other abundant ion.

Another factor contributing to the commonness of saline injury to shade trees is the use of unnecessarily large quantities of irrigation water by the homeowners in irrigating their lawns. They often use many times the amount of water a farmer would use to irrigate his crop to bring it to maturity.

Some owners whose trees have declined or died from salt accumulation from the irrigation water are reluctant to modify their management practices; but unless the practices are changed, after the trees have died the conversion of St. Augustine grass to more salt tolerant Bermuda grass might occur. This grass might then give away to more salt tolerant weeds, and then bare spots might appear in the lawn. Such shifts may portend a local desertification of the lawn through sodium accumulation and the advanced development of black alkali. Not responding to the declining and dying trees and the shifts in vegetation by changing management practices can lead to greater problems in the future. A picture on page 626 of the November 1979 National Geographic shows advanced cases (Gore 1979).

Diagnosis

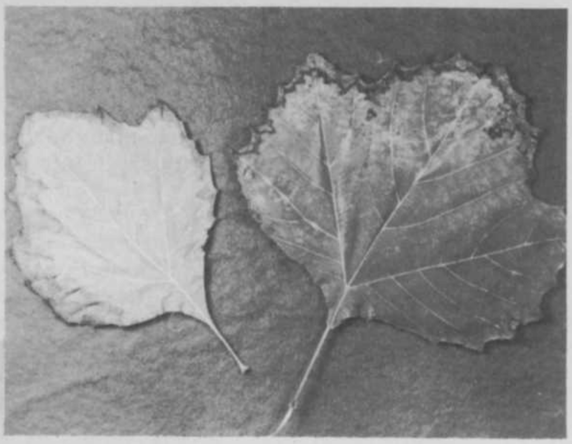
Salt in trees may come from many sources, and it has been said that the sources of salt, whether from the ocean, highway deicing, or saline soils are not important (Dirr 1976). However, there are differences in the amount of salt taken up by the leaves or the roots. For example, southern Magnolia, which has a thick glossy cutin on its leaves and does not readily absorb airborne ocean salt sprays, does readily absorb salt in the irrigation water through its roots. It is relatively more resistant to salt in the air than it is to salt in the soil solution. The gross symptoms of dieback on a post picture (p. 27) shows oak absorbing salt from low-level saline irrigation applied to a golf green.

The symptoms of salt injury are difficult to distinguish from symptoms of infection with the oak decline fungus (*Cephalosporium diospyri*). Both maladies produce thin crowns through which skylight is readily seen, both cause dieback. At times the salt produces a brown or gray peripheral injury of the leaves. In cases where the spring rains were adequate and irrigation was delayed until summer, a serial reduction in leaf size has occurred. Full sized leaves were produced in the spring, but each new set of leaves produced was smaller than the last one, and in the fall the last leaves formed were truly tiny dwarfs.

Comparative leaf symptoms of some maladies on oaks, including salt, are illustrated in another paper (Van Arsdel 1978). Salt injured trees seem to be more subject to wind breakage, and insects seem to prefer to feed on them.

Usually the separation of the fungus decline from the salt injury requires culture isolation tests for the fungus, salt (chloride) tests for the leaves, and soil tests for alkalinity and sodium content. Both maladies produce similar physiological drouths and they often occur in the same tree at the same time. Where they occur together the two kinds of physiological drouth supplement each other.

Killing the vascular wilt fungus with a systemic



Post oak by golf green exhibiting saline irrigation decline.
Sycamore leaves with perimeter scorch and shape distortion caused by saline low-level saline irrigation.

fungicide makes the trees seem to recover, with larger leaves and crown thickening, but if the saline irrigation continues, the trees continue to die back and decline. The dwarfed leaves have been found with salt injury in the absence of the decline fungus, and the trees have had dieback and eventually death from the salt, but we have not had cases in which the saline irrigation was terminated to see what effect this would have on the *Cephalosporium* infected trees. We now have a case where we can terminate the saline irrigation by using unsoftened water where salt-softened-water was the source of the sodium and chloride, and this should disclose the symptom change where the salt water intake is reduced and the *Cephalosporium* remains undisturbed.

An important part of the diagnosis for salt injury is the testing of the irrigation water for its salt content. This can be done with chloride testers (titration) or spectrophotometrically for the sodium, but in Texas all of the public water supplies are regularly tested by the State Board of Health. The results are available upon request and are also published in a book. Often the slightly saline water supply is the only water available for irrigation, and the problem is to manage the irrigation when the only supplies are saline. Some representative Texas water supplies were listed with their salt contents in my recent paper (Van Arsdel 1979).

Another aid to diagnosis of saline irrigation is the order in which the trees and shrubs show injury or die. A table of relative susceptibility is appended. This list should aid in diagnosis and in suggesting substitute plants where saline irrigation can not be avoided. This rating list carries the salt tolerance level beyond the least tolerant plants listed in the USDA Ag. Hndbk. 60, and some of our most "resistant" plants are among their "least tolerant" species. Our listing is in closer agreement with another list of salt tolerance which summarizes observations of many authors of the salt tolerance of shade trees to blown and splashed deicing salt along roads in the northeast (Uirr 1976). Together the three lists indicate that shade trees are generally less salt tolerant than field crops.

Mode of action

Salt is sodium chloride, and its solutions contain these ions independently. They act in different ways as they cause the decline of trees absorbing the salts. The chloride does not reach a high level in the soil — 50 ppm is the highest I have measured — and usually there has been less than 20 ppm. The chloride builds up to high levels in the leaves of the trees. There is usually dwarfing at levels of 1,000-3,000 ppm chloride in the leaves, and there are usually scorch symptoms at more than 3,000 ppm. I have found as much as 35,000 ppm in living leaves, although more than 6,000 ppm is exceptional. The chloride concentrations above 3,000 ppm kill tissues, and cause the perimeter scorch, but chloride is mobile in the plant, and the level often decreases during rainy weather.

Sodium builds up to high levels in soils. Levels of 2,000 ppm sodium in the soil are fairly common. This is usually indicated by extreme alkalinity (pH 8.5-9.0). The sodium builds up to the highest levels where montmorillonite clay in the subsoils prevents percolation. This clay is the fraction of the soil that absorbs the sodium and holds it. The sodium disperses the clay causing the soil to lose structure and to become hard, alkaline, and impermeable in a condition known as black alkali. Trees can not grow in a soil in this condition.

Management program to minimize damage

Management of low-level salinity irrigation problems presented here involves changing the source of water, watering less, and making physical and chemical modifications to the soil. Often alternative sources of water are not available, but most homeowners can water less. Locally, the Lufkin soil on Yegua formation parent material, permits no internal drainage through the claypan or the deep layers of clay and shale under it and thus prevents leaching, but some leaching can occur over the surface, especially in winter when there is abundant rain and low evaporation. Each of these management alternatives is considered below .

Normal procedures to manage crops with saline irrigation are (1) to grow salt tolerant crops, (2) to avoid clay in the soils, and (3) to provide excellent drainage to permit leaching (Boyko 1968). None of these alternatives are available to us. We are working with plant species more susceptible to salt than those generally considered in the saline soil and irrigation literature (Richards 1954), and with plants which are already growing on the site with no chance of moving them. The soils we are concerned with must be utilized in place, and have high montmorillonite clay contents in both the soil and subsoil. These clay soils originally had no internal drainage, but the addition of salt through saline irrigation makes them even less permeable to water. Often they are held to certain levels by streets, curbs, and gutters that were laid out with no plan for drainage.

Change the water source:

If water of very low salinity is available, then using it is a good solution. Some examples follow.

Rain barrel: Potted house plants, greenhouse plants, or any other plants under roofs and not receiving rainfall usually have salt injury. Using rainwater is a very good solution to the problem. If you have many plants or a long dry season, many barrels may be required (I use 4). A major problem is the mosquitoes who lay eggs and reproduce in the water in the barrels. Goldfish eat the mosquitoes and wigglers readily, but the water must be aerated for them to survive, and as you use up the water supply, then what do you do with the fish? The goldfish are cheap enough that you can let them die and keep replacing them, but since I am soft hearted, I find myself putting a good deal of effort into maintaining the fish. A fishpond with a relatively larger surface area makes a better reservoir than rain barrels if you want to use fish. However, you can never use chemicals to kill the algae (green scum) in the pond because these weed killers will kill the plants that are irrigated with the water.

A screen over the barrels is a good way to keep the mosquitoes out, but it must be a fine mesh, and it must be maintained to prevent holes and clogging. Other covers can be used with downspouts and overflow outlets if they are tight enough to keep the insects from entering. Inlets and outlets would require screening.

Insecticides can be used to keep the mosquitoes from living or reproducing in the water. An ounce of almost any insecticide added to 55 gallons of water will kill the larvae. Malathion was one that was effective, and that amount of insecticide had no effect on the plants. No insecticide can be used with goldfish, even a little spray drift into the barrel has killed fish of mine.

Distilled water: Most desalinization projects use distilled water. Chemical processes for removing salt seem to be expensive and difficult. The largest and cheapest source of distilled water that most of us have is the condensation water from the cooling coils of the air conditioner. Systems can be worked out to use the condensation water for lawn watering as well as for house plants, but if provisions were not made at the time the house was built, then it is usually expensive to convert the system so it can be used for watering. Window air conditioners can be used by placing a barrel under the overflow and drain to collect the condensing water. This provides good irrigation water for potted plants.

De-ionized water: A Bryan plant store who also manages plants in and around businesses uses all deionized water. For most people, deionized water is probably impractical or too expensive at this time, but improved methods should be developing.

Surface water: Many of the salts found in well water are not found in surface drainage water, especially near the source. At times this can provide a water source with a lower salt content. However, most permanent streams and rivers exchange water with underground aquifers and have fairly high salt contents. Where the watershed consists of lawns watered with saline water, the streams will have a higher salt content than the original source because of evaporation to the air and dissolving salts from the soil.

Shallower well water: Since the salts in the well water are leached from the rocks it flows through, generally, the deeper the well, the more salt in the water. Sometimes a shallower well, or a well from a different aquifer, can be found with a lower salt content.

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Susceptibility to Saline Water Irrigation

This is a subjective list of susceptibility to salt in irrigation water. It has been made from observations of plants in my own yard (Bryan water containing 48 ppm chloride & 188 ppm sodium), the TAMU campus (56 ppm chloride, 205 ppm sodium), and in other parts of the state where comparative observations could be made. It includes Wichita Falls water with 137 ppm chloride & 72 ppm sodium, and Wixon WSC water with 140 ppm chloride and 445 ppm sodium.

SUSCEPTIBLE	MODERATE	RESISTANT	
American holly	Windmill palm	Austrian pine	*Siberian elm*
Sycamore (American)	*Washingtonia filifera* (Calif. fan Palm)	Yaupon *(Ilex vomitoria)*	*Agave*
Elm (winged, cedar, and American)	Hickory (shagbark)	*Citrus*	*Yucca*
Linden	Norfolk Island pine *(Araucaria excelsa)*	*Pyracantha*	
Ginko	Pin oak	*Green ash*	
Monkey puzzle *(Araucaria imbricata)*	Black jack oak	*Ligustrum*	
Rose	Bois d' arc (osage orange)	*Japanese yew (Podocarpus macrophyllus)*	
Sweetgum	Slash pine	*Chinese holly*	
Silver maple	Post oak	*Avocado*	
River birch	Loblolly pine	*Arizona ash*	
Pecan (hickory)	Cottonwood	*Live oak*	
White ash	*Magnolia grandiflora*	*Chinese tallow*	
Buttonbush	Scotts pine	*Pindo palm*	
		Russian olive	

Order within classes is from most susceptible to most resistant. Relative values are tentative. Most plants in this list are more susceptible than those listed in USDA Handbook 60, 1954. Plants in both lists are resistant in this list and of "low salt tolerance" in the Handbook. Listings agree with those in Dirr(1976).

Unsoftened water: This problem is rare because of the cost, but I have found softened water being used for irrigation (where the softening process adds salt). The solution is to quit using softened water for irrigation. Hard water is usually less damaging to plants and soils.

Water less

Practitioners of the art of diagnosing plant problems for the private home owner often feel that an automatic watering system installation is the beginning of major plant survival problems. Many systems can not be set with great enough intervals between irrigation times, nor for long enough flow periods at each of the waterings.

Increase the time between waterings: Established St. Augustine grass lawns can generally be maintained by watering once every week or ten days. In the hottest driest weather, weekly watering is needed. After long periods of shorter cycle watering, the change to the longer cycle may have to be gradual to develop a deeper root system. Sodium in the soil and high water tables from frequent watering also contribute to shallow root systems.

Increase the amount used each time you water: Always water long enough to thoroughly wet the soil (e.g. two hours) and have abundant run-off. There must be run-off to carry any accumulated salts away, and prevent surface build-up of salt where the water is removed only by evaporation.

Do not water trees where the grass is not "show place" grass in the front yard. The tree roots extend 30 to 50 feet from the trees, and will grow out into moist soil when there is less water next to them. In prolonged drouths, water once every four weeks. In narrow shady places between houses it is best to forget about growing grass and concentrate on growing trees. In such locations, the use of a rock mulch (e.g. 1½-in. gravel) will aid in preventing evaporation, absorbing rain, and preventing weeds. Line streams or drainageways that carry water from saline supplies to beyond the reach of roots with concrete. This lining must be root proof because the roots will actively grow toward a source of moisture. If this is not possible, **Cut the roots** to stop the transport of saline water from a stream to the trees. Ditch to a depth of four feet, or to shallower claypan or caliche layer that stops the deeper penetration of the roots. Ditching should be repeated every three years. Any stream whose major watershed area is watered lawns will have an augmented salt content.

Physical and chemical modification of the soil

Make physical and chemical modifications to remove the sodium from the soil and to build granular better-drained soil. Since leaching is an important part of chemical modification, good drainage must be established. Chemical changes that release sodium must be done slowly so the sudden release of large amounts of salt does not burn or kill the plants. It is best to use no more than 400 pounds of chemicals per acre per year. Slowly dissolving granular dolomite need not be included in the 400 pounds per year.

Physical modifications: Be sure the soil is as well drained as possible so the water can percolate through to leach the salts from the soil. In such cases drainage may be expensive and could require tiling or French drains into drainage pits with sump pumps or siphons. French drains leading into pits filled with course gravel and having siphons that start themselves at overflow times can be built at a relatively low cost, especially if you do your own labor.

Use a heavy spike toothed aerator to permit air, water, and chemicals to penetrate more deeply. Applying a top dressing of sand over the freshly spiked soil may make semi-permanent access channels.

Chemical modification:

While *sulfuric acid* treatments are used in agriculture and nurseries, there is danger of burning your perennial plants, and it should probably not be used in ornamental plantings and vegetation. *Sulfur* granules may be used up to 200 pounds per acre per year. Sulfur slowly changes to sulfuric acid. *Treatment with gypsum* (hydrous calcium sulfate) is the most frequently recommended treatment for alkali. The amount of gypsum required to neutralize the alkali is several tons per acre, but applying this much would cover the soil and burn the vegetation. Adding 400 pounds per acre per year should start reversing alkalization process. The addition of dolomite granules with the gypsum should help the structure, and the magnesium dislodges sodium, increases leaf retention, and improves leaf color and vigor. Potassium excesses present in most of our soils make magnesium unavailable to plants, and coastal plain soils are often deficient in magnesium. The dolomite should not be needed in the older limestone and hill country soils. *Fertilize with ammonium sulfate* to make the soil more acid, remove sodium, and to provide nitrogen. If 100 pounds of ammonium sulfate is used, then only 300 pounds of gypsum should be used per acre per year. Phosphate fertilizer is usually not needed for woody plants, and additional potassium is harmful in these alkali soils. However, if leaching is successful at removing much of the sodium, potassium can go with it. At the higher rates of sulfate use, it may be well to add some potassium to the soil in the fertilizer. At the rates recommended here, the potassium should not become in short supply in the Lufkin soils.

Physical-chemical modification with a top dressing of course sand and peat-moss will benefit the soil and roots. Add about one-half inch per year for 4-6 years. The roots will grow up into the sandy layer to get moisture, better structure, and less salt. Grass will grow much better in the sand, and the sand will increase rainfall absorption. Do not mix the sand and peat-moss into the soil, and do not add any soil with clay in it (top soil). The object of the top dressing is to provide a better soil on top of the old one so the roots can avoid the clay. Clay is the dangerous fraction of the soil where saline irrigation is used (Boyko 1968, Richards 1954).

Making these soil modifications will start to reverse the alkali trend of the saline water irrigated soils, and in a few years the conditions should be much better. Your trees should have larger healthier leaves (you will not see the difference unless you save pressed samples). If you can not do all of the ameliorating treatments, any part of these you can do will improve the health of your trees and soil. Reducing the amount of water applied by extending the time between waterings is most important. **WTT**