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Salts influence the health of turf

Don't try to fix discolored turf without testing soil and water for salts.

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KEY POINTS

- Several tests are necessary to diagnose a salt problem in soil or water.
- Poor-quality water increases soil salts over time.
- Environmental factors such as drought or rapid evapotranspiration can elevate salts to levels that will kill turf.

Most irrigation water contains salts, and the relative amounts of salts in irrigation water influence the health of turf. Because it has become increasingly difficult to find high-quality water for turf irrigation, salt problems may become more common in turfgrass management.

Measurements of salinity

The first step in salt management is to identify the problem. Golf course superintendents need to send samples of their irrigation water and soil from different parts of the golf course to a laboratory. Specialized soil and water labs have standardized test packages for salt problems.

Here are the most important tests:

Electrical conductivity (EC) is a measure of water's salt ion concentration. It's reported in decisiemens per meter (dS/m).

Total dissolved solids (TDS) is the amount of all dissolved salts in water. It's expressed in parts per million (ppm), which is equal to milligrams per liter. Water with greater amounts of dissolved salts will have a greater TDS value.

Sodium absorption ratio (SAR) is measured as a ratio of sodium (Na^+) to calcium (Ca^{++}) and magnesium (Mg^{++}) ions. Higher SAR values increase the chances of sodium buildup in the soil. SAR is measured as:

$$SAR = Na^+ \div \sqrt{(Ca^{++} + Mg^{++}) \div 2}.$$

When the carbonate ($CO_3^=$) and bicarbonate (HCO_3^-) content of irrigation water are high, SAR is adjusted to account for the ratio of bicarbonates to calcium and the partial pressure of carbon dioxide.

Exchangeable sodium percentage (ESP) measures the amount of exchangeable sodium as a percentage of the total cation exchange capacity of the soil. High ESP indicates a greater chance of sodium buildup in the soil. The equation is:

$$ESP\ (\%) = [\text{Exchangeable sodium} \div \text{cation exchange capacity (CEC)}] \times 100.$$

ESP is required only for soil tests, but the rest of the tests are required for both soil and irrigation water. It is extremely important to set a baseline with a water and soil test in early spring, followed by one in summer and one in fall.

Residual sodium carbonate (RSC) measures the amount of magnesium and calcium relative to the carbonates and bicarbonates in water. Calcium and magnesium can counteract carbonate and bicarbonate. High RSC value indicates potential hazard with carbonates and bicarbonates. RSC is measured in milliequivalents per liter and is calculated from the milliequivalents per liter of the ions in the equation:

$$RSC = (CO_3^{=} + HCO_3^{-}) - (Ca^{++} + Mg^{++}).$$

Soil chemical reactions are generally reversible. The soil exchange complex is primarily composed of the negative sites on clay and organic matter, which serve as the adsorption sites for positively charged ions (cations) such as Na^+, Ca^{++}, K^+ and Mg^{++}. These cations are adsorbed on soil colloids by weak electrostatic forces. These adsorbed cations exchange reversibly with cations in the soil solution. All cation exchange is based on "valence." For example, sodium is monovalent (one positive charge), whereas calcium is divalent (two positive charges). During exchange, one calcium ion will replace two sodium ions and vice versa.

SAR measures the amount of sodium relative to calcium and magnesium, and hence it is the most important parameter for determining sodium accumulation. The amount of ions should be reported in milliequivalents per liter by dividing parts per million (milligrams per liter) by the equivalent weights of the respective cations.

Irrigation water can be classified-based on electrical conductivity, total dissolved solids, residual sodium carbonate and sodium absorption ratio. Soils are classified based on electrical conductivity, sodium absorption ratio and exchangeable sodium percentage.

How salt accumulates in soil

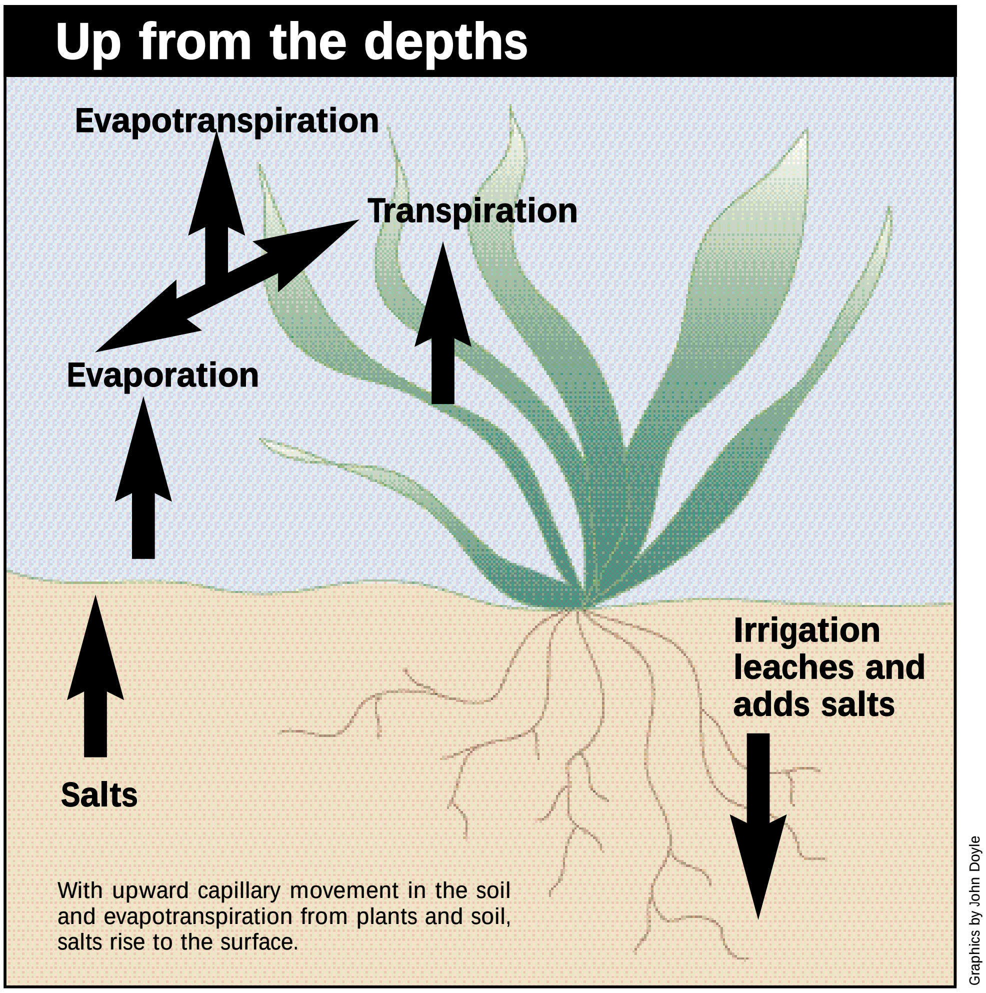
The physical forces that govern the movement of salts to the upper soil surface are evapotranspiration (ET), infiltration and capillary action. Under high temperature and low relative humidity, ET is high, so water bearing dissolved salts migrates to the soil surface through capillary action. After the water evaporates, salts remain on the soil surface.

Short-term buildup of salts

Each irrigation cycle reduces the concentration of soil salts by dilution. Later in the season, as the temperature increases and the relative humidity decreases, ET demand increases. Over time, salts concentrate, much as they would in a pot of salty water boiled on a stove. As the water evaporates, the solution becomes concentrated, yet adding water instantly dilutes it. Similarly, the soil water in a golf course becomes concentrated and may reach alarming levels, which ultimately affect the health of turf.

Long-term salt buildup

The long-term buildup of salts depends on rainfall, snowfall and other



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precipitation. In the spring, salt concentrations are generally low, but in the summer, the salts in soil solution may become concentrated because of high ET and reduced infiltration of water. Over the summer, the salt concentration might become great enough to inhibit turf growth.

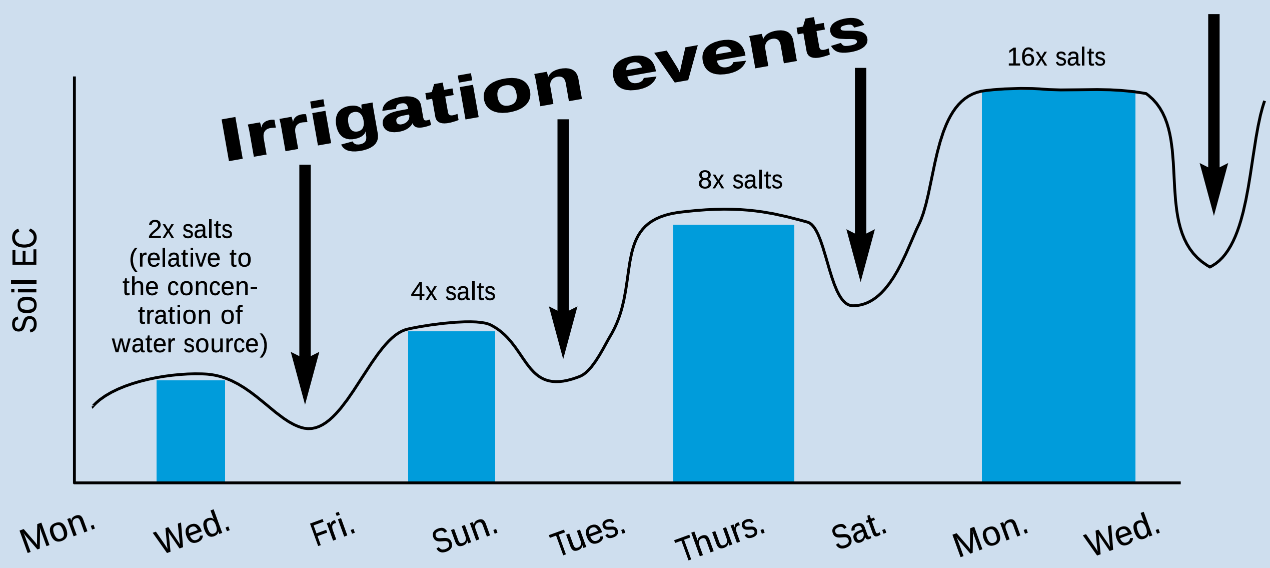
Soil electrical conductivity decreases after summer, depending on the amount of precipitation, but during drought situations, soil EC stays in the danger zone. Under such conditions, golf course superintendents often encounter salt problems. Last summer golf course superintendents in the Chicago area started observing "wet wilting" and other symptoms that led them to test their soil and irrigation water. In most instances they found high salt content and high exchangeable sodium. These were a result of drought and long-term salt buildup.

Detrimental effects on turf

Generally, plants take up water and nutrients by osmosis, in which water molecules move from a lower concentrated soil solution to a higher concentrated cell sap through a semipermeable cell membrane. Osmotic potential depends on the difference in concentration of the soil solution vs. cell sap. When excess salts increase the concentration of the soil solution, the osmotic gradient changes, and plants cannot take in water through osmosis. The turf shows moisture stress and starts wilting. At very high concentrations of salt in the soil, osmotic potential reverses the direction of water flow from plant cells into the soil solution and the cells collapse. This phenomenon, called *plasmolysis*, kills plants.

In a high salt concentration, the turf can no longer take up water, and plants experience physiological drought. Because the irrigation schedule has not changed, a superintendent might not realize that the turf is experiencing drought. Of course, adding fertilizer at this time will increase the soluble ions in

Short-term salt increases



Irrigation temporarily dilutes salts in soils but also carries additional salt into the soil. With drying, the soil's salt concentration increases. Excess irrigation or heavy precipitation can correct the problem, but routine irrigation can worsen the problem.

the soil solution and cause greater drought stress. Rather than attempting to diagnose the problem by merely looking at the turf, the superintendent should test the soil and water.

Cation exchange capacity

Cation exchange capacity is the maximum capacity of a particular soil to hold cations onto its negative sites. Negative sites in soil are provided by organic matter and clay minerals. Sand particles are composed mainly of quartz, which is inert in nature. Sand greens cannot hold nutrients.

Carbonates and bicarbonates

The carbonates and bicarbonates in irrigation water react with the available calcium and magnesium in soil solution to form insoluble calcium carbonate or bicarbonate and magnesium carbonate or bicarbonate. The presence of a high concentration of sodium ions leads to the replacement of calcium and magnesium ions from the clay complex. As soon as the calcium and magnesium are released into the soil solution, they react with the available carbonates and bicarbonates and settle out as precipitates.

Calcium reactions

$$Ca^{++} + CO_3^{=} \rightarrow Ca(CO_3)$$

$$Ca^{++} + HCO_3^{-} \rightarrow Ca(HCO_3)_2$$

Magnesium reactions

$$Mg^{++} + CO_3^{=} \rightarrow Mg(CO_3)$$

$$Mg^{++} + HCO_3^{-} \rightarrow Mg(HCO_3)_2$$

Effect of sodium on soil structure

Sodium is a monovalent ion and has a larger atomic radius than calcium or magnesium. Sodium disperses soil colloids, soil particles block the pore spaces and infiltration rates are reduced. At high levels, sodium ions displace calcium and magnesium from the soil exchange complex. These calcium and magnesium ions react with the free carbonates and bicarbonates to form insoluble precipitates. In turn, sodium-dominated soil particles are dispersed, leading to poor aeration and a reduction in infiltration rates. To have a better soil structure and increased soil aggregate stability, the soil particles need to be flocculated with polyvalent cations such as calcium and magnesium.

Acknowledgments

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References

1. Carrow, R.N., R.R. Duncan and M. Huck. 1999. Treating the cause, not the symptoms. *USGA Green Section Record* 37(6):11-15.
2. Throssell, C. 1996. Controlling salts in golf course soils and irrigation water. *Golf Course Management* 64(9):61-64.

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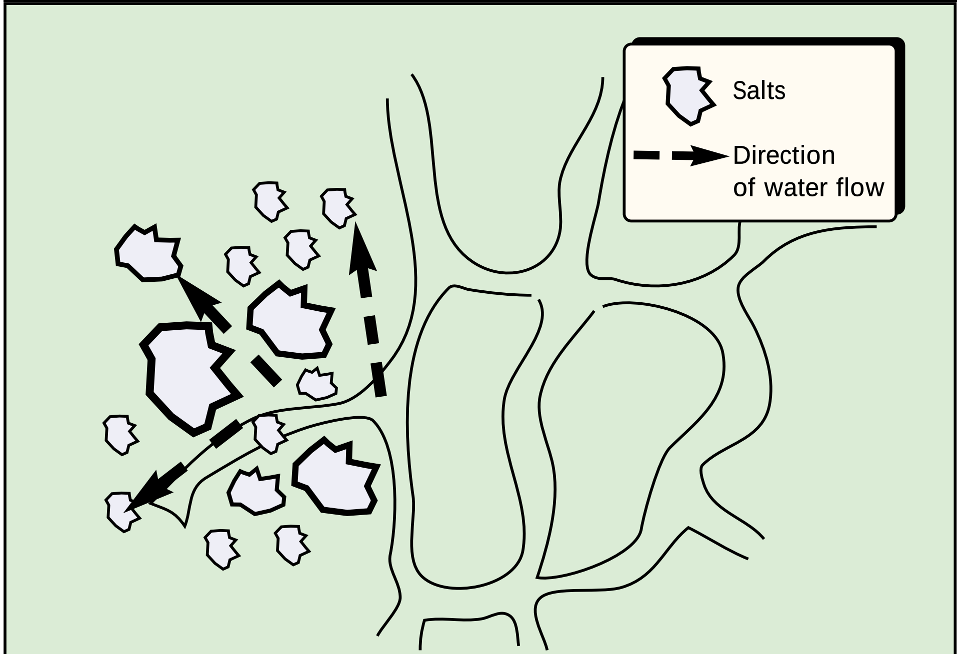
Salts parch plants



In a soil-and-root system, water flows toward high salt concentrations. When the salts in soil moisture exceed the concentrations in cell sap, water leaves the plant and the plant will die.