UNIVERSITY OF DELAWARE
COOPERATIVE EXTENSION

Soils and Salts

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What are Salts?

Salts are natural components of soil, surface, and groundwater. They are ionic mineral compounds, which means they are bonded by electrostatic attractions between cations (+ charge) and anions (- charge). Some salts, like table salt (NaCl), are highly soluble in water, while others, like the mineral $CaCO_3$ (lime), are less soluble. Agricultural production is largely concerned with soluble salts that will dissociate into ions in the soil, reducing germination and plant growth. (Figure 1.)

Figure 1: Germinating and younger plants are very susceptible to high levels of salts in the root zone.. Photos courtesy: Jarrod Miller.

Common Salts in the Soil

Plants take up essential nutrients as soluble ions, so many salts will be familiar in plant production (Table 1). They include the cations Ca^{+2}, Mg^{+2}, K^{+} as well as the anions Cl^{-}, SO_4^{-2}, B^0, and NO_3^{-}. Other salts that contribute to soil salinity include Na^{+}, CO_3^{-2}, and HCO_3^{-}. Typically, NO_3^{-} and K^{+} are not high in saline soils, while carbonates are mostly present in alkaline soils. While plants need soluble salts for nutrient uptake, excessive amounts will limit growth.

Table 1: Common salts found in saline soils.

Cations	K^{+1}, Na^{+1}, Mg^{+2}, Ca^{+2}
Anions	HCO_3^{-1}, CO_3^{-2}, SO_4^{-2}, B^0, NO_3^{-1}, Cl^{-1}

Sources of Salts

Soil Mineral Weathering

Soils are naturally composed of inorganic minerals, including primary minerals (e.g., quartz, micas, or feldspars) and their weathering products, including clay minerals and oxides or hydroxides. As primary minerals weather, they release salts, which will accumulate in soils if rainfall or leaching are low. In contrast, salts are leached out of soils in areas with adequate rainfall, such as the Mid-Atlantic. The most likely salts to leach are bases (Ca^{+2}, Mg^{+2}, K^{+}), leading to acidic soil conditions.

Soil Biology and Carbon Dioxide

Plants can remove nutrient salts from the soil through nutrient uptake. They may also cause salts to concentrate as they remove water through evapotranspiration. Along with soil microorganisms, plants also release CO_2 into the soil. When CO_2 reacts with water it creates carbonic acid (H_2CO_3). The free acid (H^{+}) from this reaction will cause the weathering of soil minerals discussed above, further increasing soil salts.

Rainfall (Cyclic Salts) and Salt Sprays

Salts in the atmosphere provide the catalyst for condensation that leads to raindrops, so rainfall will contain a minor, but measurable amount of salts. These salts may be derived from the ocean or atmospheric dust and are known as *cyclic salts*. Some ions measured in rainwater include Cl^{-}, Na^{+}, Mg^{+2}, Ca^{+2}, and K^{+} (USGS, 1962). Chloride is higher in

rainfall near the coasts, while rainfall concentrations of Ca^{+2} and K^{+} will increase as you move inland (Cassidy, 1968). Communities and landscapes directly on the coast will also receive *salt spray*, derived from wave action along the coastline, affecting plant composition.

Fossil Salts

Some regions of the United States have fossil salts, formed from prior deposits or marine sediments (Cardon et al, 2014). These may be mined for fertilizers (e.g., KCl) and can be a source of salinity if they are solubilized and moved into soil horizons through groundwater, runoff, or irrigation waters.

Anthropogenic (Man Made)

Fertilizer salts are designed to be soluble to allow for efficient plant uptake during the growing season. Salinity issues with fertilizers will be localized around the seed and limited concentrations should be placed in-furrow. Similar issues may be observed for foliar applications directly to plant leaves, causing salt burns at high concentrations.

Salts can also be added to soils through irrigation waters, which can raise the soil salinity above crop tolerances. The salinity of irrigation water does not have to be high to cause issues with plant growth. If a soil has poor drainage or limited leaching, salts will accumulate over time.

Poor Drainage, High Water Tables, and Evaporation

Soils can be poorly drained for several reasons, including high clay contents, root restricting layers, or compaction. These physical restrictions can slow water movement causing ponding in soils and the accumulation of salts. Saline groundwater from high water tables may also increase salinity in the root zone by capillary rise.

Saltwater Intrusion, Tidal Flooding, or Stormwater Surges

Coastal regions may receive salts from saline or brackish water delivered by irrigation, tidal flooding, or hurricane stormwater surges. This inundation issue is separate from salt spray, which is atmospheric. These effects may also be cumulative and not mutually exclusive. Sources will be both surface and groundwater.

Salinity Issues on the Delmarva Peninsula

The Delmarva coastline, extending along the Chesapeake to the Delaware Bay, is surrounded by saline and brackish waters (Figure 2). While the Mid-Atlantic receives adequate rainfall for leaching salts, the gentle topography of the Delmarva coastal plain is poorly drained. This may lead to the accumulation of salts from irrigation, capillary rise, or saltwater intrusion. Drainage channels meant to lower the water table may also become conduits for tidal flooding and hurricane surges. Reclamation of agricultural fields will vary based on topography, available drainage, and the frequency of salt additions.

Figure 2: Stormwater surge and high tides reducing yields along coastal Delmarva fields. Photos courtesy: Jarrod Miller

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