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DEPARTMENT OF AGRICULTURAL ENGINEERING

CAI 334 IRRIGATION WATER QUALITY AND WASTE WATER MANAGEMENT

UNIT 2 IRRIGATION WATER QUALITY

2.2 SALINITY AND PERMEABILITY

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Salinity and permeability Problem

Salinity, or the concentration of salts in soil or water, can have significant effects on the permeability of plants. Here's how:

1. **Water Uptake**: Salinity affects the osmotic potential of the soil solution. When soil salinity increases, the water potential of the soil solution decreases, making it more difficult for plants to take up water. High salinity levels can create an osmotic gradient that pulls water out of plant cells, leading to dehydration and reduced permeability.
2. **Ion Toxicity**: High levels of salt in the soil can lead to the accumulation of toxic ions such as sodium (Na+) and chloride (Cl-) in plant tissues. These ions can disrupt cellular processes and damage cell membranes, affecting their permeability. As a result, the ability of cells to regulate the movement of water and solutes across their membranes is compromised.
3. **Root Function**: Salinity stress can also affect root structure and function. High salt

concentrations in the soil can inhibit root growth and reduce root surface area, which decreases the plant's ability to absorb water and nutrients. Additionally, salt stress can lead to the formation of toxic concentrations of ions in the roots themselves, further impairing their function and affecting permeability.

4. **Stomatal Regulation**: Salinity stress can disrupt the normal functioning of stomata, the small pores on the surface of leaves that regulate gas exchange and water loss. High salt levels can cause stomatal closure, reducing transpiration and water loss from the plant. While this may help conserve water in the short term, it can also reduce the uptake of carbon dioxide needed for photosynthesis, ultimately affecting plant growth and permeability.
5. **Cellular Damage**: Salinity stress can cause direct damage to plant cells, including membrane disruption and oxidative stress. This damage can compromise the integrity of cell membranes, affecting their permeability and ability to maintain proper ion and water balance. Overall, salinity stress can disrupt multiple physiological processes in plants, leading to reduced permeability and impaired growth and development. Plant species and varieties vary in their tolerance to salinity, with some being more adapted to saline conditions than others.

IV. How salinity affects crop growth

Salinity, or the concentration of salts in soil or irrigation water, can significantly impact crop growth and productivity. Here's how:

1. **Osmotic Stress:** High salt concentrations in the soil create an osmotic imbalance, making it more difficult for plants to absorb water. This leads to water stress in plants, even when water

is present in the soil. Plants must expend more energy to take up water, which can stunt growth and reduce yields.

2. **Ion Toxicity:** Sodium (Na^+) and chloride (Cl^-) ions, commonly found in saline soils, can accumulate in plant tissues to toxic levels. These ions interfere with various physiological processes, such as photosynthesis and nutrient uptake, ultimately damaging plant cells and tissues.
3. **Nutrient Imbalance:** High soil salinity can disrupt the balance of essential nutrients in plants. For example, excessive sodium can affect the uptake of potassium (K^+), calcium (Ca^{2+}), and magnesium (Mg^{2+}), leading to deficiencies of these nutrients. This imbalance can impair enzyme functions and metabolic processes vital for plant growth.
4. **Root Damage:** Salinity can cause root damage directly by dehydrating root tissues and indirectly by promoting the accumulation of toxic ions. Damaged roots are less efficient at absorbing water and nutrients, further exacerbating stress on the plant.
5. **Reduced Photosynthesis:** Salinity stress can impair photosynthesis, the process by which plants convert light energy into chemical energy. High salt concentrations can disrupt chloroplast structure and function, decrease chlorophyll content, and inhibit the activity of enzymes involved in photosynthetic carbon fixation. As a result, plants produce fewer carbohydrates, which are essential for growth and yield.
6. **Stomatal Closure:** To conserve water and minimize salt uptake, plants often close their stomata (tiny pores on leaf surfaces) in response to salinity stress. However, stomatal closure restricts gas exchange and reduces carbon dioxide uptake for photosynthesis, further compromising plant growth and productivity.
7. **Decreased Crop Yield and Quality:** Collectively, the adverse effects of salinity on plant physiology and metabolism can lead to decreased crop yields and inferior crop quality. Yield losses may vary depending on the crop species, its stage of growth, and the severity and duration of salinity stress.

To mitigate the negative impacts of salinity on crop growth, farmers can employ various strategies, including selecting salt-tolerant crop varieties, improving soil drainage, implementing efficient irrigation practices, and applying soil amendments to reduce salt accumulation. Additionally, ongoing research into genetic and agronomic solutions continues to offer promising avenues for addressing salinity stress in agriculture.

V. SALINITY AND YIELD

WATER SALINITY

Irrigated agriculture in Utah depends on adequate, high-quality water supplies. As the level of salt increases in an irrigation source, the quality of that water for plant growth decreases. All irrigation waters contain some salt. In many areas, good quality (low salt and low sodium) water is not available for irrigation, consequently waters containing high levels of salt must be used. A measure of water salinity that is important for crop yield is Electrical Conductivity (EC). EC is measured in units of deci-siemens per meter, or dS/m. The higher the EC the higher the level of salts in the water and the more difficult it is to grow plants with that water. Increasing salinity affects growth mainly by reducing the plants ability to absorb water.

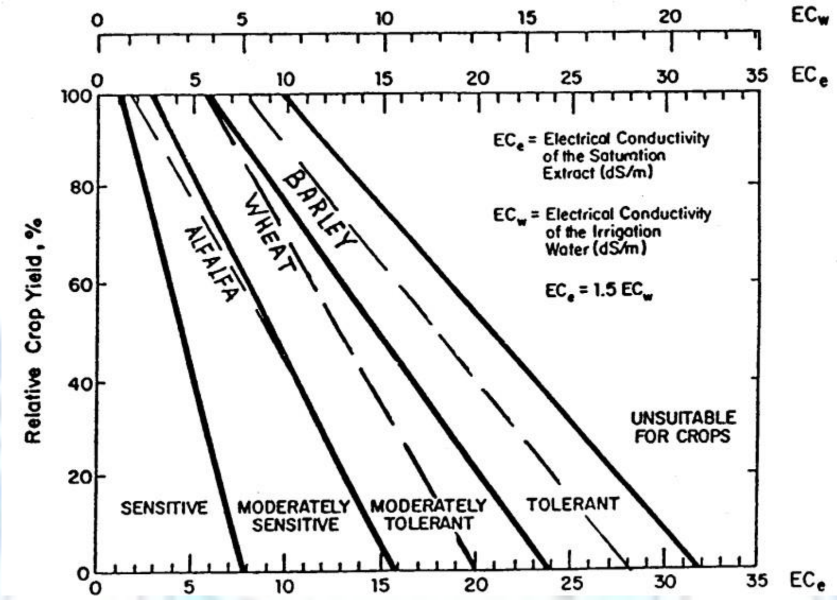
CROP YIELD RESPONSE TO SALINITY

Considerable study relating crop yield response to waters of different salinities has been summarized in "Water Quality for Agriculture" (1). Generally, crops are classified into four major groups: sensitive, moderately sensitive, moderately tolerant, or tolerant of salinity in irrigation waters.

Table . Relative salinity tolerance categories for typical Utah crops (listed in order of decreasing tolerance). Salinity tolerance information for additional crops can be obtained from reference 3 at the end of this guide.

Tolerant	Barley, Sugar Beet, Wildrye, Asparagus
Moderately Tolerant	Wheat, Wheat Grass, Zucchini, Beet (red)
Moderately Sensitive	Tomato, Cucumber, Alfalfa, Clover, Corn, Muskmellon, Potato
Sensitive	Onion, Carrot, Bean, Apple, Cherry, Raspberry, Strawberry

Possible yield response of various crops to different levels of salinity is shown in Figure below. The relationship between ECe (the EC of the soil saturation extract) and ECw (the EC of the irrigation water) is indicated on the graph. When sufficient irrigation water is applied to cause 15% of the water to percolate through the root zone, then the ECe is approximately equal to 1.5 ECw. This deep percolation of water through the root zone is necessary to continue leaching of accumulated salts out of the active root areas. For example, if the ECw is 5 dS/m, then the ECe would be approximately 7.5 dS/m and the expected yield of alfalfa would be only 60% of what it could be with better quality water. This still assumes that 15% of the applied water moves down through the root zone as deep percolation to leach salts out. If the irrigation system design or operation is such that the application rate just meets the plant requirements and there was no leaching, the expected yield would be less than that shown on the graph.



VI. MECHANISM OF SALT TOLERANCE BY PLANTS

I. Avoidance: Avoidance is the process of keeping the salt ions away from the parts of the plant where they are harmful.

1. Salt Exclusion
2. Salt Extrusion
3. Salt Dilution
4. Compartmentation of ions

II. Tolerance

Done by Osmotic adjustment

Hormone synthesis - ABA stress hormone, hardens plants against excess salts

Crop tolerance is the degree to which a crop can grow and yield satisfactorily in saline soil. Different crops vary widely in their response to salinity. Some can tolerate less than 2 dS/m and others up to and above 8 dS/m. Salt tolerance also depends considerably upon cultural conditions and irrigation management practices. Many other factors such as plant, soil, water and climate interact to influence the salt tolerance of a crop

Ion Regulation and Sequestration: Salt-tolerant plants efficiently regulate the transport and distribution of ions within their tissues. They may actively transport excessive sodium ions into vacuoles or specialized salt glands, reducing their accumulation in sensitive cellular compartments.

Osmotic Adjustment: Salt-tolerant plants maintain water uptake and turgor pressure by accumulating compatible solutes, such as proline, glycine betaine, and soluble sugars, in their cells.

Anatomical and Morphological Adaptations: Some salt-tolerant plants exhibit specialized anatomical and morphological adaptations that enhance their ability to cope with saline conditions. These adaptations may include reduced leaf surface area to minimize water loss through transpiration, succulence to store water, and the development of salt glands or bladders to excrete excess salts.

Salt exclusion

The ability to exclude salts occurs through filtration at the surface of the root. Root membranes prevent salt from entering while allowing the water to pass through.The red mangrove is an example of a salt-excluding species.

Salt excretion/extrusion

Salt excreters remove salt through glands or bladders or cuticle located on each leaf.

Salt bladders - eg) *Atriplex* , *Mesembryanthemum crystallinum L.*

Salt glands - active process, selective for sodium and chloride(eg) Black and white mangroves

Secretion through cuticle – eg) *Tamarix* Salt glands- dump sites for the excess salt absorbed in water from the soil; help plants adapt to life in saline environments.

Salt Dilution

By dilution of ions in the tissue of the plant by maintaining succulence.Plants achieve this by increasing their storage volume by developing thick, fleshy, succulent structures Succulence is mainly a result of vacuoles of mesophyll cells filling with water and increasing in size. This mechanism is limited by the dilution capacity of plant tissues

Compartmentation of ions

Organ level - high salts only in roots compared to shoots especially leaves .At cellular level- high salts in vacuoles than cytoplasm thus protecting enzymes

VII. ROOT ZONE SALINITY AND AVOIDANCE MEASURES

Root zone salinity refers to the concentration of salts in the immediate vicinity of plant roots within the soil. When soil contains high levels of soluble salts, such as sodium chloride (NaCl), calcium sulfate ($CaSO4$), or magnesium sulfate ($MgSO4$), it can lead to elevated salinity in the root zone.

The average root zone salinity can be calculated using the average of five points in the rooting depth.

This accumulation of salts can occur due to various factors, including:

1. **Natural Processes:** Salts may be naturally present in the soil due to factors such as weathering of minerals, geological formations, and the accumulation of salts from groundwater or surface water sources.
2. **Irrigation Practices:** In agricultural settings, improper irrigation practices can contribute to root zone salinity. For example, excessive use of irrigation water without proper drainage can lead to the accumulation of salts in the soil over time.
3. **Poor Water Quality:** The quality of irrigation water can influence root zone salinity. Water sources with high salt content, such as saline groundwater or recycled wastewater, can contribute to salt buildup in the soil if not properly managed.

Climate Conditions: Arid and semiarid climates with low rainfall and high evaporation rates are more prone to soil salinization. In these environments, salts can accumulate near the soil surface as water evaporates, leading to increased salinity in the root zone.