CHAPTER THIRTY-ONE

Salt Injury

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A salt is a chemical compound that breaks down in water into electrically charged particles called ions. In a soil system, soluble salts are defined as those inorganic chemicals that are more soluble than gypsum ($CaSO_4$). The principal soluble salts in the soil contain the cations sodium (Nat calcium (Ca"), and magnesium (Mg") and the anions chloride (C1), sulfate (SO_4), and bicarbonate (HCO3). Other ions, such as carbonate (CO_3) and boron (B), can sometimes be present.

Salts may be either damaging or beneficial depending on the characteristics of the specific chemicals involved and the total salt concentration. Ordinary table salt (NaCl) is toxic to plants, whereas magnesium sulfate ($MgSO_4$) can be used as a fertilizer. Soluble salts in forest nurseries can come from several sources. They can occur naturally in the soil, or they can be introduced in saline irrigation water, through overfertilization, or from salt-contaminated mulches.

Soluble salts can injure woody plant seedlings in four different ways, depending on the total salt concentration and the specific salt ions involved:

• A high total soluble-salt concentration can cause an osmotic effect—the salt ions can chemically reduce the water available to the seedling.

• The permeability and water infiltration rate of the soil are reduced because high relative concentrations of sodium salts cause soil particles to disperse.

Table 31-1. Guidelines for interpreting result of electrical conductivity (EC) tests of irrigation water and soil. Ratings, expressed in microSiemens per centimeter (mcS/cm), show adequate, marginally high, and excessive levels of salinity.

	ADEQUATE	MARGINALLY HIGH	EXCESSIVE
Irrigation water	0 to 500	500 to 1,500	>1,500
Soil (saturation extract)	750 to 2,500	2,500 to 4,000	>4,000

• High levels of certain ions, including sodium, chloride, and boron, are directly toxic to plants.

• An imbalance of salts that are also nutrients, such as calcium, can reduce the availability of other mineral nutrients, such as iron or phosphorus.

Obviously, the diagnosis of salt injury is a complex subject. Only the osmotic effect of high total salt levels will be considered here, because that is the most widespread problem. The other three specific ion effects cause problems on a more local basis. Because the diagnosis and treatment of these problems is more complicated, additional information can be obtained from the references supplied at the end of this chapter.

High soluble salt concentrations reduce the osmotic potential, and therefore the total water potential, of the soil solution. This, in turn, reduces the water that is available to the roots of seedlings, causing a type of physiological drought. This osmotic effect is particularly damaging during seed germination and seedling emergence, but can also cause problems with larger stock if the soil is allowed to dry out excessively.

Occurrence: species and season

All seedlings are susceptible to salt injury to some degree. Germinants and young seedlings are particularly vulnerable because of their succulent nature, whereas older seedlings and other stock types, such as transplants, are more tolerant. Small-seeded or slow-growing species like spruces and firs are often more susceptible because they take longer to grow out of the young, succulent stage.

Whereas the salt tolerance of most agronomic crops has been established, that of many species of Pacific Northwest forest tree seedlings has never been determined. Most commercially produced nursery stock should be considered susceptible, however. Pine seed-

A

B

C

D

Figure 31-1. Foliar symptoms caused by salt injury: (A) chlorosis, (B) and (C) scorched needle tips, and (D) mosaic growth pattern of normal and stunted seedlings.

lings are generally more salt-tolerant than very susceptible species such as Douglas-fir and spruces. There is variation within *Pinus*, however; lodgepole pine is less tolerant than ponderosa pine. Susceptibility to salt damage does not change during the growing season, although there is more potential for injury when seedling tissue is succulent or during periods of high moisture stress.

Symptoms

In germinating seeds and emerging seedlings, mortality caused by salt injury may be mistakenly attributed to damping-off. In larger seedlings, visual symptoms of salt injury will vary among species, stock types, and ages of the seedlings. Salt-affected seedlings may exhibit foliar chlorosis, scorched needle tips or leaf margins, or a patchy, mosaic growth pattern of normal and stunted seedlings (Figure 31-1). Seedlings growing in saline soils often do not develop fibrous root systems. Soils dominated by calcium salts often exhibit white surface crusts (Figure 31-2) that effervesce when tested with a drop of dilute acid (Figure 31-3). Soils with a high proportion of sodium salts, on the other hand, are blackish in color and have a slippery texture.

Salt injury may be confused with
Damping-off
Pesticide damage
Mineral nutrient problems

Salt injury car ot be identified by visual symptoms alone. Accurate diagnosis requires a comprehensive evaluation, including chemical analysis of soil, irrigation water, and seedling tissue. The best measure of the total soluble-salt level in irrigation water or soil is the electrical conductivity (EC) test, which can be performed with a conductivity meter. Because salt ions conduct electricity, an EC test can measure the salt concentration in an aqueous solution. The EC of irrigation water can be tested directly. The EC of a soil sample is measured using a saturation extract, which is obtained by adding enough distilled water to soil to form a thick paste and extracting the soil solution. EC tests can measure only total soluble salts, not levels of individual salt ions. Table 31-1 gives general guidelines for interpreting EC test results. SI units are microSiemens per centimeter (mcS/cm), which are equivalent to the older units of micromhos per centimeter (mcmhos/cm). Soil samples should be collected at a number of different depths but especially from the surface, because salts often wick to the surface when water evaporates from the soil.

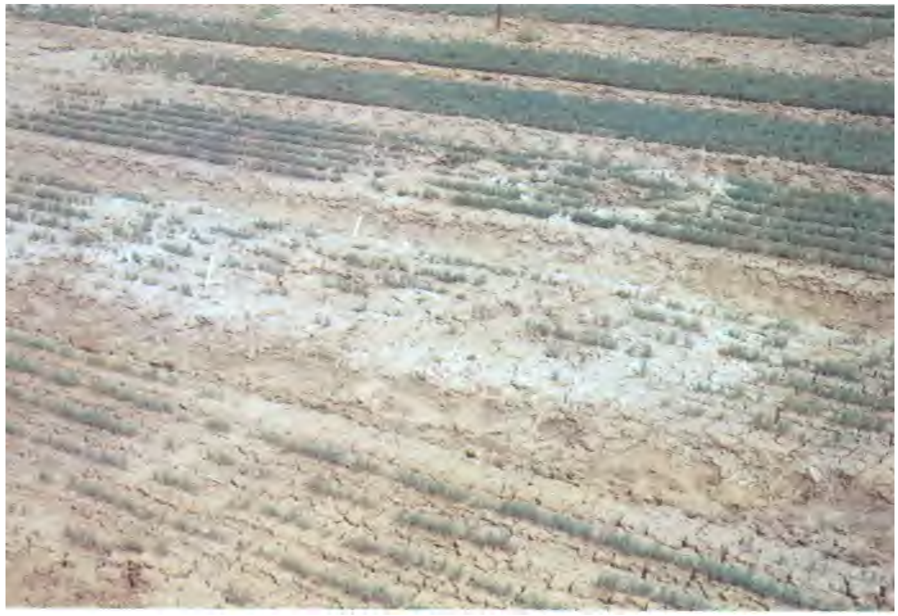

Figure 31-2. Soils dominated by calcium salts often exhibit white surface crusts.

Salt injury symptoms appear:
All ages
Any time throughout rotation

Predisposing factors

Salt injury can occur without any predisposing stress factors, although hot, dry weather can increase the potential for damage. Poor irrigation practices that allow the soil to dry out will concentrate the salts in the soil solution. In particular, brief irrigations used for cooling seedlings during hot weather can increase the salinity in surface soils.

Poor soil-management practices can lead to accumulation of salts in the seedling root zone, especially in fine-textured soils. Improper or excessive soil cultivation can break down soil structure, reducing porosity and inhibiting water infiltration and drainage. Repeated use of heavy equipment in seedbeds can produce impermeable soil "pans" within the soil profile, further restricting drainage.

Figure 31-3. The presence of excessive calcium salts can be confirmed by placing a drop of dilute acid on the soil to see if effervescence occurs.

Loss potential

Mortality during the germination period can be significant, but these losses often go unnoticed, especially if the damage is done before the seedlings emerge. With older seedlings, growth losses are difficult to quantify because the growth rate may be significantly reduced before the stunting becomes evident. Stunted seedlings result in increased cull rates, particularly when they are scattered throughout the seedbeds, because they make it necessary to lift and grade entire seedbeds.

Management

CULTURAL

The best solution is to avoid salinity problems in the first place by judicious selection of nursery sites. Soils that are inherently saline can be identified during site selection, but even initially productive nursery soils can be ruined with moderately saline irrigation water. Therefore, both soil and irrigation water should be evaluated for salinity problems; not only for total soluble salts but also for the relative concentration of specific salt ions. Soil permeability and porosity should also be tested when evaluating nursery sites, because they determine the leaching potential of the soil.

In established nurseries, managers should conduct intensive soil surveys of their seedling production areas to identify the least-saline soils for producing salt-sensitive species. More-tolerant species and stock types, such as transplants, can be planted in the more-saline nursery blocks.

The only way to remove soluble salts from the soil is to leach them from the soil profile with deep irrigation—applying large amounts of water to the soil to dissolve the salts and carry them down below the root zone. Obviously, leaching will be more effective if irrigation water with a low salt content is used. These irrigation treatments should be scheduled during the fallow year, after the soil has been deep-ripped to break up any impermeable hardpan layers. Incorporation of relatively large amounts of organic matter will help increase the porosity of most soils, and gypsum amendments can improve soil structure in high-sodium soils. Deep irrigation is particularly effective in reducing the salt concentration in surface soil layers during the critical seed germination and emergence period. This treatment must be monitored carefully, however, to ensure that soils do not become waterlogged. Once the seedlings are established, deep irrigation is more difficult to accomplish, but it can be scheduled immediately after wrenching when the soil is most porous.

Mulches may be used to decrease evaporation from the soil surface and keep salt crusts from developing. Light-colored mulches are better because darker mulches absorb heat, which can girdle succulent seedlings. Hydromulch is effective when applied immediately after sowing. A thin layer of sawdust is also an effective mulch; it can be applied either to the sown seedbed or over existing seedlings. Sand mulches should be tested to make sure they are not calcareous.

Because inorganic fertilizers are also salts, only products with a low salt index should be considered for use on saline soils. A series of small fertilizer applications is less likely to cause injury than one or two large applications. Organic fertilizers such as sludge or animal manures may contain high salt levels and should be carefully analyzed before they are purchased for use in forest nurseries. Even sawdust can be saline if the logs were stored in salt water for long periods.

CHEMICAL

There is no simple way to treat the soil chemically to correct a salinity problem. Sodium-affected soils can be treated with gypsum amendments of about 22.4 mt/ha (10 tons/ac) to improve soil porosity and prepare it for leaching.

If the soil contains insoluble calcium carbonate, that salt can be chemically converted to the more soluble gypsum with amendments of elemental sulfur at rates of 560-1,120 kg/ha (500-1,000 lb/ac). These sulfur treatments will also lower the soil pH. Because it is slow to react, sulfur should be applied at least a year before the seedling crop is sown.

Selected references

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