February 15, 2022

VEN 101B – Salinity and Grapevines (Guest Lecture – Dr. Christopher Chen)

I. Scope of the problem

- Worldwide millions of acres of fertile land are affected by salt (NaCl). In California alone, tens of thousands of acres in the San Joaquin Valley and near the coast are subject to soil salinization.
    - ◊ In Paso Robles 29-43% of soil surfaces are salt affected
- Sodium chloride contamination has been a source of concern for agriculture since ancient times (e.g., Carthage and Palestrina)
- Today, widespread use of NaCl in road icing control and other forms of sodium and chloride are used in cleaning or food products. The use of KCl in winery cleaning products has increased chloride levels in vineyards that use reclaimed water from their wine production processes.

II. All about NaCl

- Like in animals, sodium and chloride are essential micronutrients for most plant species. However, when exposed to excess volumes of NaCl both sodium and chloride can become toxic to grapevines.
- Because Na^+ is similar is size and charge to potassium (K^+), sodium can act as an imposter for potassium and enter the plant through protein transporters (e.g., *HKT 1;1*) in the cell membrane specific to moving potassium. Potassium is a macronutrient in grapevines and used in many processes. When sodium replaces potassium, the Na^+ ion becomes toxic rapidly in most plant species.
- Similarly to Na^+ and K^+, chloride (Cl^-) can enter grapevines through the same pathways as nitrate (NO_3^-). This is due to their similar ionic size and charge. However, grapevines and citrus are more sensitive to Cl^- than Na^+ and will often succumb to chloride toxicity symptoms before sodium toxicity becomes a leading cause of decline.

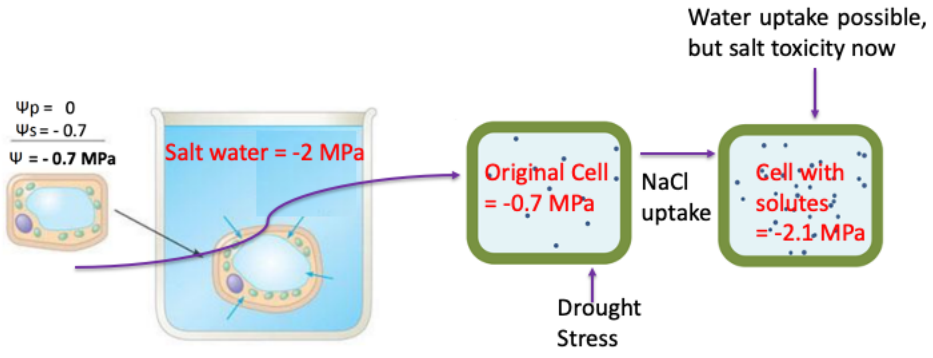
III. Salt toxicity thresholds

- Salt tolerance in grapevines is most commonly associated with chloride exclusion from the shoots, leaves, and fruit. Similar to phylloxera tolerance in rootstocks, salt tolerance is based on the ability of the vine to continue functioning normally under adverse conditions rather than negating the detrimental factor altogether.

- The level of salinity exposure is relevant to the success of any salt tolerant rootstock with the average level of soil salinity that is considered toxic being 40mM/L or about 4 dS/m. This is equivalent to about 7% the average NaCl concentration of seawater.
- Some rootstock varieties have been tested under NaCl concentrations of 12.5% seawater and still performed successfully.

IV. Stages of stress response

- **Osmotic shock** - this is the response that occurs when the osmotic effect of NaCl impacts the cells of the vine. Salt draws water out and thus decreases the water potential around the cell. This stage mimics drought stress. However, cells can acclimate by incorporating some of the surrounding NaCl into their vacuoles or by producing compatible solutes. These balance out the cell water potentials to then be more negative than the saline water around them and allows the vine to take up water again. Similar to how shockingly cold a swimming pool can be when you first jump in, but not so cold once your body acclimates to the temperature around it.
- **Ion Toxicity** – As the plant accumulates salts to balance out the water potentials in its cells, it can eventually accumulate too much NaCl. This accumulation of salt ions results in the toxic response from the plant that can lead to its decline and death.

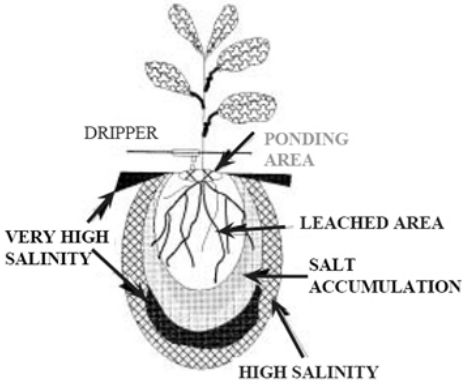


V. Sources of NaCl

- NaCl can come from many sources besides the weathering of parent material.
- Some of the most common are fertilizers and cleaning compounds. Many fertilizers and cleaning compounds have Cl^- in their formulation. Potassium

chloride (KCl) is a good example of this and is often used as a fertilizer for potassium. However, when the water is reclaimed, and the potassium has been utilized it concentrates chloride each time this occurs.

- This kind of salt concentration would not happen without poor water reclamation practices where salts are not filtered out of the water, or without a heavy reliance on groundwater for irrigation.
- When groundwater is used for irrigation, salts in the upper soil horizons may leach down into the water table and salinize the source irrigation water over time. Drip irrigation, while good for water conservation, can keep these salts concentrated in the upper soil layers where rooting occurs.



VI. Salt Tolerance in Grapevines

- Salt tolerance can come in many forms and often is the result of multiple approaches by the plant to mitigate salt accumulation and damage.
    - ◊ Root architecture, growth habit, and response
    - ◊ Restrictions on cellular uptake
    - ◊ Xylem loading by parenchyma cells
    - ◊ Recapture by xylem parenchyma
    - ◊ Phloem loading into fruits
    - ◊ Excretion onto leaf surfaces (but not in grapes)
- Of these methods, loading salts into parenchyma cells is one of the most studied for grapevines and occurs more often in grapevines with higher reported NaCl tolerance. This is similar to how Mangroves capture salt from sea water in their roots before they shed them.

VII. Breeding for salt tolerant rootstocks

- Some wild grapevines have been shown to exclude more chloride from their leaf tissues.
- When crossed with a more salt-susceptible grape variety the offspring showed a continuous range of chloride exclusion from leaf and petiole tissues. This suggests that this form of salt tolerance is a phenotypic trait controlled by many genes.
- This form of salt tolerance in grapevine occurs during the long-distance transport of chloride from roots to shoots. Roots all had similar levels of chloride accumulation, while leaf chloride levels differed drastically among the offspring.
- Using traditional breeding methods to introduce chloride tolerance into grapevine rootstocks may be a viable method to developing salt-tolerant rootstock cultivars.

VIII. Rootstock Recommendations for high NaCl tolerance

- *Strong salt excluders:*
  - ◊ 140 Ru, Schwarzmann, St. George, 99 R
- *Yield maintained, but less salt exclusion:*
  - ◊ 1103P, 110R
  - ◊ Rootstocks related to *V. riparia* will often decline in yields
- *Yield maintained, but poor salt exclusion*:
  - ◊ Ramsey (Salt Creek)
- *Very poor salt exclusion:*
  - ◊ 039-16, 44-53 M, Dog Ridge, *V. vinifera* (own roots)