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Crop Salt Tolerance

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Soil salinity is an important stress affecting irrigated crops in many areas of California. This stress is often exacerbated during drought years. Over time, salts can accumulate in the soils as crops extract water leaving the salts behind in the root zone. Without sufficient leaching, accumulated salts will eventually reach a level that will damage crops. Even irrigation water low in salinity, salts will eventually build up in the soil to damaging levels without sufficient leaching from rainfall or excess irrigation water.

Under drought conditions, high quality surface water supplies may not be available in sufficient quantities to meet crop needs and may be supplemented or completely replaced with poorer quality ground or surface water. Ironically, irrigation water higher in salinity will require more water in order to maintain the same level of soil salinity. That is, poorer quality water requires more leaching. But regardless of the quality of the water applied, deficit irrigation combined with poor quality water will exaggerate the salinity problem.

All soils and irrigation water contains dissolved salts, but these salts vary in both concentration and composition. The major dissolved salts are the cations, sodium (Na^+), calcium (Ca^{2+}) and magnesium (Mg^{2+}), and the anions, chloride (Cl^-), sulfate (SO_4^{2-}) and bicarbonate (HCO_3^-). Typically ground water has naturally higher concentrations of these constituents and some soils have higher salinity than others. These dissolved salts can be growth-limiting when concentrations in the root zone exceed critical levels as described further below.

Salinity is best characterized by the electrical conductivity (EC) of the irrigation water (ECw) or the EC of the saturated soil paste (ECe); the higher the dissolved salt concentration, the higher the EC. The units of EC are expressed in dS/m or mmhos/cm where 1 dS/m = 1 mmho/cm. For EC values less than 5 dS/m, 1 dS/m = 640 mg/L total dissolved solids (TDS) and 1 dS/m = about 800 mg/L for EC values above 8 dS/m.

ECe is an important parameter because it is this value that is used to characterize crop salt tolerance. All crops can tolerate a certain level of salts up to a critical threshold (ECt), beyond which yields decline in linear fashion. Critical ECt values vary among crops, as do the rates of yield decline with increasing soil salinity (i.e. slope of yield decline) beyond this threshold.

Crop tolerance to salinity and specific ions

Crops respond not only to the total concentration of dissolved salts in the water but also to specific constituents (or ions) as well. Responses to salinity are categorized as either osmotic' or "specific ion" effects. **Osmotic effects** occur because of the concentration of salt in the soil solution, with no reference to the kind of salts present, is excessive to optimal production or crop quality. Therefore excess fertilizer salts can suppress crop growth just like table salt (NaCl). **Specific ion effects**, on the other hand, occur due to chloride (Cl^-), sodium (Na^+) and/or boron (B) that accumulate in the plant causing specific damage or visual injury. High concentrations of sodium can also cause nutritional imbalances in the plant. Although difficult to quantify the contribution of growth suppression by either 'osmotic' or 'specific ion' effects, 'osmotic' effects are thought to be the dominant growth suppressing effect in annual crops, while 'specific ion' effects can become the dominate growth suppressing effect in tree and vine crops. Unfortunately, long-term studies on salt damage to tree crops are lacking. This publication addresses crop damage due to 'osmotic effects'.

Crop salt tolerance

The most common whole-plant response to salt stress is a general stunting of growth. This is an osmotic effect. As salt concentration in the rootzone increases above a threshold level (ECt), both the growth rate and ultimate yield of the crop progressively decrease. The salt-stressed plant is smaller than non-stressed plants but otherwise appears healthy unless salinity is extreme (see Figure 1). However, the threshold and the rate of growth reduction vary widely among different crop species. In a field of annual crops the canopy may take on a wave like appearance and barren spots may be observed. This is largely due to the variability of soil salinity across the field.

Figure 1. Osmotic effects showing decreased growth of celery as EC of the added salts in the soil water increases from 0 to 12 dS/m.

Crop salt tolerance is defined based on the crops ability to maintain yield and quality with increased salinity. The salt tolerance of crops can be described as a function of yield decline across a range of salt concentrations expressed as the average rootzone salinity (Figure 2). Salt tolerance can be adequately characterized on the basis of two parameters: 1) a "threshold" parameter (EC_t) which is the maximum rootzone salinity that the crop can tolerate above which yields decline and 2) the "slope" which describes the rate by which yields decline with increased soil salinity. Salt sensitive plants have low thresholds and steep slopes while salt tolerant plants have higher thresholds and lower slopes.

Where data are available, the potential yield function for a particular crop can be plotted in a similar manner to the lines grafted on Figure 2. While thresholds (ECt) and slopes vary among crops, most crop-specific lines fall in between the tolerance boundary lines drawn in Figure 2. Depending upon where these lines fall will give their general salt tolerance ranking as "salt sensitive", "moderately salt sensitive", "moderately salt tolerant" or "salt tolerant". For example, a crop with a yield threshold (ECt) of 2.0 dS/m and yield of 50% at 7 dS/m, would be classified as "moderately salt sensitive".

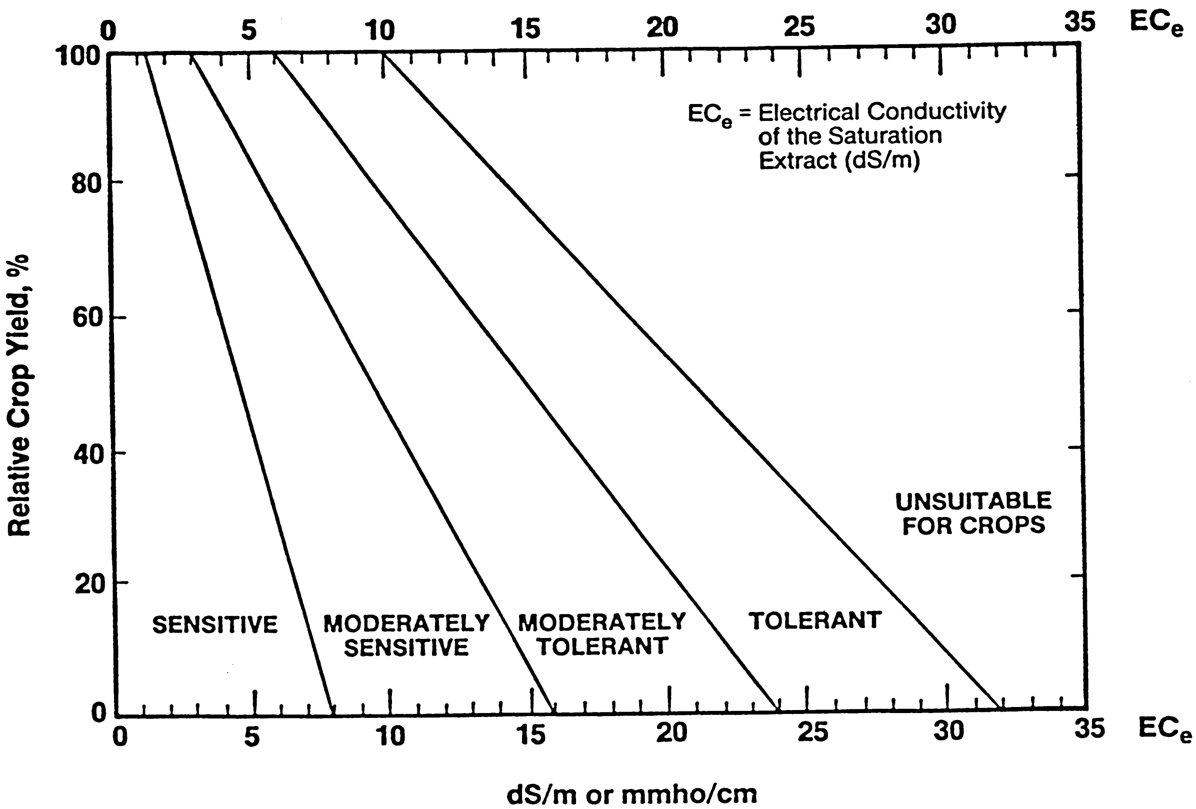

Figure 2. Relative crop yield (or yield potential) as a function of average rootzone salinity (ECe, dS/m) grouped according relative tolerance or sensitivity to salinity (Adapted from Maas and Grattan, 1999; Grieve et al., 2012).

In Table 1, a list is provided of different crops and their tolerant rankings. The crop tolerance ranking from Table 1 can be used with Figure 2 to get a general estimate of the yield potential for a given rootzone salinity (ECe). Note that most tree and vine crops, the category falls in 'senstive' or 'moderately senstive'. For grass and forage crops, many fall within the 'moderately tolerant' to 'tolerant' classes. For more specific information on yield potentials form individual crops, see drought tips entitled "Water quality guidelines for vegetable and agronomic crops" and "Water Quality guidelines for Trees and Vines".

Monitoring and Management

- **Minimize water stress.** During drought years, it is important not to impose a water stress (i.e. underirrigation) when a salinity stress is present. The combination of the stresses can be devastating for the crop.

- **Monitor the soil.** It is important to monitor the soil root zone for changes in salinity and boron concentrations. Corrective actions will be required if there is a steady increase over time.
- **Leach soil.** If the salinity in the rootzone is approaching yield-reducing levels, more irrigation water is needed to leach the salts from the rootzone. Typically leaching over the winter, rainy season is generally more effective at leaching salts when the evaporative demand is near zero and the grower can take advantage of the non-saline rainwater and smaller amounts of high quality water.

Table 1. Salt tolerance ratings of various crops. (Maas and Grattan, 1999; Grieve et al., 2012)

Herbaceous Crops			
Sensitive	**Moderately Sensitive**	**Moderately Tolerant**	**Tolerant**
Rice, paddy	Artichoke, Jerusalem	Lesquerella	Barley
Sesame	Chick pea	Roselle	Canola
	Corn	Safflower	Cotton
	Crambe	Sorghum	Guar
	Flax	Soybean	Kenaf
	Peanut	Sunflower	Millet, channel
	Sugarcane	Wheat	Oats
			Rye
			Sugarbeet
			Triticale
			Wheat, semidwarf
			Wheat, Durum
Grasses and Forage Crops			
Sensitive	**Moderately Sensitive**	**Moderately Tolerant**	**Tolerant**
Gram, black or Urd bean	Alfalfa	Barley (forage)	Alkaligrass, Nuttall
Pea, Pigeon	Bentgrass, creeping	Brome (mountain)	Alkali sacaton
	Bluestem, Angleton	Brome (smooth)	Bermudagrass
	Broadbean	Canarygrass, reed	Kallargrass
	Buffelgrass	Clover (Hubam, sweet)	Kikuyugrass
	Burnet	Dhaincha	Oats (forage)
	Clover (alsike, berseem, Iadino, Persian, red, strawberry, white Dutch)	Fescue [tall, meadow (Festuca)]	Rye (forage)
	Clover	Guinea grass	Salt grass, desert
	Clover	Hardinggrass	Wheatgrass, fairway crested
	Corn (forage)	Rape (forage)	Wheatgrass, tall
	Cowpea (forage)	Recuegrass	Wildrye, Altai
	Dallisgrass	Rhodesgrass	Wildrye, Russian
	Foxtail, meadow (Alopecurus)	Ryegrass (Italian, perennial, Wimmera)	
	Glycine	Sudangrass	
	Grama, blue	Trefoil, narrowleaf birdsfoot	
	Lablab bean	Wheat (forage)	
	Lovegrass	Wheat Durum (forage)	
	Milkvetch, Cicer	Wheatgrass, standard crested	
	Millet, Foxtail	Wheatgrass, intermediate	
	Oatgrass, tall	Wheatgrass, slender	
	Orchardgrass	Wheatgrass, slender	
	Panicum, blue	Wheatgrass, western	
	Sesbania	Wildrye, beardless	
	Siratro	Wildrye, Canadian	
	Sphaerophysa		
	Timothy		
	Trefoil, big		
	Trefoil, broadleaf birdsfoot		
	Vetch		

Vegetable and Fruit Crops			
Sensitive	**Moderately Sensitive**	**Moderately Tolerant**	**Tolerant**
Bean (common, mung)	Cassava	Artichoke	Asparagus
Carrot	Brussels sprouts	Bean, lima	Swiss chard
Fennel	Cabbage	Beet, red	
Gram, black or Urd bean	Cauliflower	Broccoli	
Onion (bulb)	Corn, sweet	Celery	
Parsnip	Cucumber	Cowpea	
Pigeon pea	Eggplant	Purslane	
Strawberry	Garlic	Squash, zucchini	
	Kale	Turnip (greens)	
	Kohlrabi	Winged bean	
	Lettuce		
	Muskmelon		
	Okra		
	Onion (seed)		
	Pea		
	Pepper		
	Potato		
	Pumpkin		
	Radish		
	Spinach		
	Squash, scallop		
	Sweet potato		
	Tepary bean		
	Tomato		
	Tomato, cherry		
	Turnip		
	Watermelon		
Woody Crops			
Sensitive	**Moderately Sensitive**	**Moderately Tolerant**	**Tolerant**
Almond	Castorbean	Coconut	Date Palm
Apple	Grape	Fig	Guayule
Apricot	Macadamia	Guava	Jambolan plum
Avocado	Papya	Jujube, Indian	Jojoba
Banana	Pecan	Olive	Natal plum
Blackberry	Pomegranate	Pineapple	Tamarugo
Boysenberry	Plum; prune	Pistachio	
Cherimoya	Pomegranate	Scarlet wisteria	
Cherry (sweet, sand)	Popinac, white		
Currant			
Gooseberry			
Grapefruit			
Lemon			
Lime			
Loquat			
Mandarin orange; tangerine			
Mango			
Orange			
Passion fruit			
Peach			
Pear			

Persimmon			
Pummelo			
Raspberry			
Rose apple			
Sapote, white			
Walnut			

† These values serve only as a guideline to relative tolerances among crops. Absolute tolerances vary, depending upon climate, soil conditions, and cultural practices. The data are applicable when rootstocks are used that do not accumulate Na^+ or Cl^- rapidly or when these ions do not predominate in the soil.

References

Grieve, C.M., S.R. Grattan and E.V. Maas. 2012. Plant Salt Tolerance In Agricultural Salinity Assessment and Management (W.W. Wallender and K.K. Tanji, eds). ASCE Manuals and Reports on Engineering Practice No. 71, 2nd edition. 405-459. American Society of Civil Engineers (ASCE). Reston, VA

Läuchli, A. and S.R. Grattan. 2007. Plant growth and development under salinity stress. In. Advances in molecular-breeding towards salinity and drought tolerance. M.A. Jenks, P.A. Hasegawa and S.M. Jain, eds. Springer-Verlag pp. 1-31.

Maas, E.V. and S.R. Grattan. 1999. Crop yields as affected by salinity. In R.W. Skaggs and J. van Schilfgaarde (eds) Agricultural Drainage. Agron. Monograph 38. ASA, CSSA, SSSA, Madison, WI pp. 55-108

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