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DROUGHT TIP

Water Quality Guidelines for Vegetable and Row Crops

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Introduction

Salinity can have a detrimental impact on irrigated crops in many areas of California, and this is often exacerbated under drought conditions. While all soils and irrigation water contain dissolved salts, these salts vary in both concentration and composition depending on their location. These salts are dissolved in the irrigation water and soil water surrounding the roots of crops, forming ions such as sodium (Na^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), chloride (Cl^-), sulfate (SO_4^{2-}), and bicarbonate (HCO_3^-). Other ions also exist but in smaller concentrations. A soil is not considered saline until the salt concentration in the root zone is high enough to reduce crop growth and yields. Vegetable and row crops have varying degrees of tolerance to soil salinity. And soil salinity is influenced by the salinity of the irrigation water and management practices.

In the field, vegetable and rows crops mildly affected by salinity may not show it visually and yet their yields may be negatively impacted. As salinity increases, the canopy may take on a wavy, uneven-growth appearance, as salt stress is more prevalent in some parts of the field and less in others. In severely impacted areas, barren spots may appear with white salt deposits on the surface. Surrounding the barren spots there may be severely stunted plants with deep blue-green foliage, some exhibiting burn along the margins of older leaves.

Salinity of the irrigation water and soil solution is expressed by electrical conductivity (EC), and the internationally accepted reporting unit for EC is deciSiemens per meter (dS/m). (This unit is equal to millimhos per centimeter [mmhos/cm], which equal 1,000 micromhos per centimeter [µmhos/cm]). Because dissolved salts form ions in solution, the solution conducts an electrical current. For the range that salinity begins to impact most vegetable and row crops, the EC is directly proportional to the salt concentration. Salinity of the irrigation water is expressed as EC_w. Soil salinity is expressed as either the EC of the soil water (EC_{sw}) or EC of the saturated soil extract (EC_e). The latter term is the one used to characterize salt tolerance among crops and relative yield decline with increasing salinity.

Root zone salinity (EC_e), the parameter used to express the yield potential of a particular crop, increases as the leaching fraction (the fraction of irrigation water applied to the field that drains below the root zone) decreases for a given irrigation water salinity (EC_w). Over the long term, increasing the leaching fraction (LF) when using saline water can result in the same EC_e as when using lower-salinity water applied with a lower LF. In drought conditions, therefore, when only water with a higher salinity level is available for irrigation, more water should be applied to increase the LF and lower the root zone EC_e, which will lessen the effects of salinity on crop growth. Over the long term and in the absence of significant rainfall, a good estimate of the relationship between irrigation water (EC_w) and average root zone salinity (EC_e) is that EC_e equals 1.5 EC_w. This relationship assumes that the leaching fraction is maintained between 15 and 20 percent, and this is the assumption used in this publication for estimating the yield potential for various vegetable and row crops, based on the salinity of the irrigation water.

Unlike tree and vine crops, vegetable and row crops are not particularly susceptible to sodium (Na^+) and chloride (Cl^-) damage, even though these may be the dominant ions that increase the overall salinity in the water. Therefore, the guidelines provided below are based on the salinity of the water or soil water as measured by the EC.

Water Quality Guidelines

The maximum irrigation water salinity (EC_w) that can be used to achieve varying yield potentials for vegetable and row crops is provided in table 1. For example, the EC_w values at 100 percent yield represent the poorest-quality water that, if used continuously, will produce EC_e levels equal to the salinity thresholds (i.e., the maximum salinity a particular crop can tolerate beyond which yields decline). These guidelines assume that the soils are well drained and that a 15 to 20 percent leaching fraction is achieved over the long term. And it is assumed that the plant is not under any other kind of stress, neither biotic (e.g., root disease, insect pressure, weed infestation) nor abiotic (water stress, water logging, nutrient imbalance, etc.), and it is only salinity stress that is causing yield declines.

Short- versus Long-Term Use of Water

The guidelines provided here are based on the long-term use of the given water quality and do not account for rainfall or other sources of water that could be used to leach salts from the root zone. Typically, poorer-quality water can be used on a short-term basis without causing yield declines.

If the soil profile has low salinity at the beginning of the season, which can occur after a rainy season or an adequate preplant irrigation with low-salinity water, a higher-salinity water can be used over the short term without adverse effects. For example, a saline water that would reduce the yield potential by 25 to 50 percent if used continuously over the long term could be used to irrigate the crop after it is established with low-salinity water. In many cases a crop can be irrigated with this higher-salinity water for half to two-thirds of the season. However, this strategy typically does not work for consecutive years, as the root zone salinity remains high after the first season. To be successful, adequate rainfall or preplant leaching needs to occur prior to the subsequent crop. If the applied saline water is also sodic (high sodium adsorption ratio, SAR > 5), rainfall or good-quality water applied

Table 1. Salt tolerance ratings of various crops

Crop	Yield potential (%)*				Tolerance ranking†	
	100	90	75	50	Salinity	Boron
	EC of the irrigation water (dS/m)					
alfalfa	1.3	2.2	3.6	5.9	MS	T
artichoke	4.1	4.6	5.5	7.0	MT	MT
asparagus	2.7	6.1	11.1	19.4	T	VT
barley	5.3	6.7	8.7	12.0	T	MT
bean, common	0.7	1.0	1.5	2.4	S	S
bean, lima	—	—	—	—	MT	S
bean, mung	1.2	1.5	2.0	2.8	S	S
cassava	—	—	—	—	MS	—
cotton	5.1	6.4	8.4	12.0	T	VT
beet, red	2.7	3.4	4.5	6.4	MT	T
broccoli	1.9	2.6	3.7	5.5	MS	MS
Brussels sprouts	—	—	—	—	MS	—
cabbage	1.2	1.9	2.9	4.6	M	MT
carrot	0.7	1.1	1.9	3.0	S	MS
cauliflower	1.9	2.6	3.7	5.5	MS	MT
celery	1.2	2.3	3.9	6.6	MS	VT
corn, sweet	1.1	1.7	2.5	3.9	MS	MT
cowpea	3.3	3.8	4.7	6.0	MT	MT
cucumber	1.7	2.2	2.9	4.2	MS	MS
eggplant	0.7	1.7	3.1	5.6	MS	—
fennel	0.9	1.4	2.0	3.0	S	—
garlic	2.6	3.1	3.8	4.9	MS	T
kale	—	—	—	—	MS	—
lettuce	0.9	1.4	2.1	3.4	MS	MS
muskmelon	0.7	1.5	2.7	4.6	MS	MT
okra	—	—	—	—	MS	—
onion (bulb)	0.8	1.2	1.8	2.9	S	VT
onion (seed)	0.7	1.5	2.8	4.8	MS	—
parsnip	—	—	—	—	S	—
pea	2.3	2.9	3.8	5.4	MS	MS
pepper	1.0	1.5	2.2	3.4	MS	MS
pigeon pea	—	—	—	—	S	—
potato	1.1	1.7	2.5	3.9	MS	MS
pumpkin	—	—	—	—	MS	—
radish	0.8	1.3	2.1	3.4	MS	—
rice	1.9	2.6	3.4	4.8	S	—
spinach	1.3	2.2	3.5	5.7	MS	—
squash, scallop	2.1	2.6	3.2	4.2	MS	T
squash, zucchini	3.1	3.8	4.9	6.7	MT	MT
strawberry	0.7	0.9	1.2	1.7	S	S
sugar beet	4.7	5.8	7.5	10.0	T	T
sweet potato	1.0	1.6	2.5	4.0	MS	S
Swiss chard	4.7	5.8	7.6	10.5	T	—
tomato	1.7	2.3	3.4	5.0	MS	T
tomato, cherry	1.1	1.9	3.0	4.8	MS	—
turnip	0.6	1.3	2.5	4.3	MS	MT
turnip (greens)	2.2	3.8	6.1	8.0	MT	—
watermelon	—	—	—	—	MS	—
winged bean	—	—	—	—	MT	—
wheat	4.0	4.9	6.3	8.7	T	S

KEY: S = sensitive; MS = moderately sensitive; MT = moderately tolerant; T = tolerant; VT = very tolerant. Referring to concentrations of boron in the soil water, S = 0.5–1.0 mg/L; MS = 1.0–2.0 mg/L; MT = 2.0–4.0 mg/L; T = 4.0–6.0 mg/L; and VT = > 6.0 mg/L. Em dash (—) = data not available.

Sources: Maas and Grattan 1999; Grieve et al. 2012.

* Based on data presented in Grieve et al. 2012.

† These values serve only as a guideline to relative tolerances among crops. Absolute tolerances vary, depending on climate, soil conditions, and cultural practices.

could cause reduced soil-water infiltration unless surface applications of gypsum were previously applied.

Tolerance to Boron

Certain vegetable and row crops are sensitive to boron (see table 1). Boron can accumulate in the plants and cause specific injury to the margins of older leaves (boron-immobile species) or the growing tips (boron-mobile species). Unlike boron-immobile plants, plants that are boron mobile can take boron from leaves and translocate it to growing tips. Generally, leaf injury needs to be severe to cause substantial yield losses, but injury to the growing tips can be more detrimental. The crops in table 1 have been rated as sensitive (S), moderately sensitive (MS), moderately tolerant (MT), tolerant (T), and very tolerant (VT) to boron, but the ranking does not necessarily reflect boron's mobility in the plant. The maximum permissible boron concentrations in the soil water that crops can tolerate without yield reduction for these categories are 0.5–1.0 mg/L (S); 1.0–2.0 mg/L (MS); 2.0–4.0 mg/L (MT); 4.0–6.0 mg/L (T); and > 6.0 mg/L (VT). Where cool, moist climatic conditions prevail, greater levels of boron can be tolerated. Similar to the case with salinity, short-term durations of irrigation water of higher boron levels can be tolerated more than continued long-term use of water with lower boron concentrations. Soil texture influences the time required for injury to occur. The finer the soil texture, the longer it will take for injury to occur, because finer-textured soils can adsorb more boron. But boron is more difficult to leach in the soil than are salts. More water is required to leach boron from fine-textured soils than from course-textured soils.

Monitoring and Management

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 a crop. Rather, it is important to monitor the soil in the root zone for increases in salinity and boron over time to make sure they do not approach critical levels. (Use the table in this publication to determine the critical level.) If the salinity in the root zone is approaching critical levels, more irrigation water is needed to leach the salts from the root zone. For more information, see UC ANR Publication 8550, *Drought Tip: Managing Salts by Leaching* (Cahn and Bali 2015). Typically, the more effective time for leaching salts is over the winter rainy season, when the evaporative demand is near zero.

Summary

- Vegetable and row crops have varying degrees of tolerance to salinity and boron.
- Many crops can be irrigated with water that has an EC_w of 2 dS/m and boron of 2 mg/L and still maintain 90 percent yield potential.
- Crops can be irrigated on a short-term basis or in cool, moist climates using water of a poorer quality than guidelines indicate without incurring reduced yields.

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