BUL322

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Irrigating With High Salinity Water [1]

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In humid areas such as Florida, salinity concerns are different than in arid areas since large amounts of rainfall will wash out salts concentrating in the soil profile. However, management may be required close to the coast where groundwater salt content is frequently high. Salinity management also may be required during extended drought periods.

In arid climates, where most of the crop water requirement is supplied through irrigation and the water often contains large amounts of dissolved salts, salinity control is frequently a major objective of irrigation management.

Irrigation with various types of waste water (municipal, industrial, etc.) can also create salinity hazards or toxicity problems. Above certain concentrations, sodium, chloride, boron, and other ions are toxic to many plants.

Salinity

Since water is a very good solvent, all irrigation waters contain some dissolved salts. Electrical conductivity is a reliable index of salt concentration in the water. A conductivity of 1 dS/m (decisiemens per meter) indicates a salt concentration of approximately 700 ppm (parts per million)(Soil and Container Media Electrical Conductivity / IFAS Circular 1092). This value will vary to some extent with temperature and type of salts. Salinity is also frequently expressed in mg/l (milligrams per liter). The number of mg/l is equivalent to ppm. Decisiemens per meter is the SI unit for conductivity. The common English unit is millimhos per centimeter (mmho/cm). One dS/m is equal to one mmho/cm.

The salt concentration in the plant root zone is usually higher than that of irrigation water. Salts are concentrated due to evaporation and plant transpiration which selectively remove water leaving salts in the soil. These salts can be removed from the plant root zone by leaching.

Salinity Effects

Salinity restricts the availability of water to plants by lowering the total water potential in the soil. Salinity also has an impact on crop physiology and yield. Visible injury can occur at high salinity levels. Usually, crop yield is independent of salt concentration when salinity is below some threshold level, then yield gradually decreases to zero as the salt concentration increases to the level which cannot be tolerated by a given crop. This relationship is presented graphically in Figure 1 .

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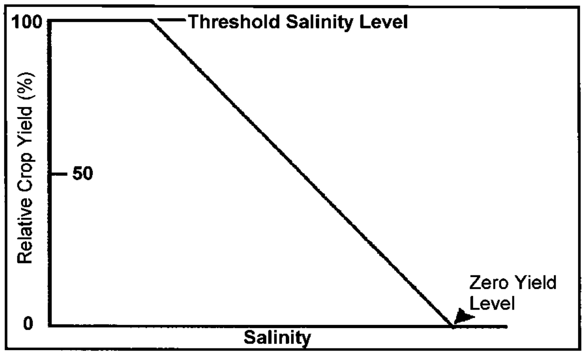

Figure 1. A general function of yield response to salinity.

Various crops show different sensitivities to different salinity levels. Some crops are much more tolerant than others. Plants are generally divided into four salinity rating groups: sensitive, moderately sensitive, moderately tolerant, and tolerant (Table 1).

Table 1. Threshold and zero yield salinity levels for four salinity groups.

Salinity Rating	Threshold Salinity	Zero Yield Level
	dS/m	dS/m
Sensitive	1.4	8.0
Moderately Sensitive	3.0	16.0
Moderately Tolerant	6.0	24.0
Tolerant	10.0	32.0
(adopted from Jensen, 1980)		

Table 2. Example of crops in four salinity rating groups.

Sensitive	Moderately sensitive	Moderately tolerant	Tolerant
almond	alfalfa	red beet	sugarbeet
apple	broccoli	safflower	cotton
avocado	cabbage	olive	date palm
bean	tomato	soybean	bermuda-grass
carrot	lettuce	wheat	
grapefruit	corn	ryegrass	
orange	cucumber	wheatgrass	
lemon	grape	wildrye	
okra	peanut		
onion	potato		
strawberry	radish		
peach	rice		
plum	sugarcane		
(adopted from Jensen, 1980)			

Table 2 lists examples of crops in each of those tolerance rating groups.

Salinity Control

In saline conditions, soil water availability to the crop can be accomplished through several strategies such as; leaching salts from the soil profile, maintaining high soil water content in the root zone, selecting more salt tolerant plants, improving drainage in the field, changing irrigation method, and adjusting planting practices in some cropping systems.

Leaching salts from the root zone

In arid climates irrigation must supply all water requirements of the crop for the growing season. Additional water must be applied to remove the salts from the root zone in order to avoid a build-up of salts which will exceed the threshold level for a given crop and result in yield reduction. The amount of additional water is usually expressed as a leaching fraction which is a dimensionless number. The leaching requirement for sprinkler and surface irrigation can be expressed by (Equation 1).

$$LF = D_d/D_i = EC_i/EC_d \qquad (1)$$

Equation 1.

where:

LF -leaching fraction (dimensionless)

D_d -depth of water drained (inches or mm)

D_i - depth of water applied through irrigation (inches or mm)

Ec_i - electrical conductivity of irrigation water (mmho/cm or dS/m)

EC_d -electrical conductivity of drainage water (mmho/cm or dS/m)

In humid areas the rainfall partially reduces the salinity problems due to irrigation with saline water. Total depth of water applied is a sum of irrigation depth and the rainfall depth minus runoff as seen in, Equation 2 .

$$D_a = D_i + D_r \quad (2)$$

Equation 2.

where:

D_i -depth of irrigation (inches or mm)

D_r -depth of rainfall minus runoff (inches or mm)

D_a -depth of the total water application (inches or mm)

The weighted average electrical conductivity for the water applied through irrigation and the rainfall which percolates through the root zone must be taken into consideration. The weighted average electrical conductivity of the total water applied can be calculated from Equation 3 :

$$EC_a = (D_r\, EC_r + D_i\, EC_i)/(D_r + D_i) \quad (3)$$

Equation 3.

In humid climates such as Florida's, there are many large rainfall events. Most of the water infiltrates quickly due to the sandy texture of the soils. During the rainy season the depth of rainfall in Equation 3 is much larger than the depth of irrigation, and the electrical conductivity of the weighted average is low. As a result, salts and fertilizer nutrients are washed from the root zone before salinity concentration can significantly increase. However, salinity may be a problem during extended dry periods when water is applied only through irrigation. During this time, an additional amount of water should be applied with each irrigation event to assure salt removal from the plant root zone. The amount of additional irrigation water can be calculated using Equation 1.

Example 1:

Calculate the leaching requirement for broccoli during an extended dry weather period in Florida (assume that all the water requirement is supplied through irrigation) knowing:

- Amount of water that must be applied to fulfill crop water requirement (CR) is 1 inch (25 mm) per irrigation event.
- Irrigation water conductivity is 1.5 dS/m.

From Table 2, we know that broccoli is a moderately sensitive crop which will be affected by the soil saturated extract salinity level ECe in the root zone higher than 3.0 dS/m (Table 1). This will allow us to calculate LF (Equation 1).

The total water applied through the irrigation system during each irrigation event (D_i) is the croop water requirement (CR) plus a drinage depth (D_d) due to the leaching requirement:

$D_i = CR + D_d$.

Using Equation 1:

$$\mathbf{LF = D_d/D_i = EC_i/(5EC_e - EC_i) = 1.5/13.5 = 0.11}$$

and since:

$$\mathbf{D_d = D_i \times LF \text{ and } D_d = D_i \times LF \text{ and } D_i = CR+D_d}$$

$$\mathbf{D_d = (CR + D_d) \times LF = (CR + D_d) \times 0.11}$$

$$\mathbf{D_d = 0.11 + 0.11\, D_d}$$

$$\mathbf{0.89\, D_d = 0.11}$$

$$\mathbf{D_d = 0.12 \text{ in}}$$

$$\mathbf{D_i = 1 + 0.12 = 1.12 \text{ in.}}$$

A simple check of calculations can be performed using equation (1):

$$D_d/D_i = LF$$

$$0.12/1.12 = 0.11$$

Answer: During dry season, the total amount of irrigation water which must be applied during each irrigation event in order to maintain the soil salinity level below 3.0 dS/m is 1.12 inch (28 mm). From this total amount, 0.12 inch (3 mm) will drain due to the required leaching fraction LF = 0.11.

Salinity Under Microirrigation

Due to the continous high water content in the root zone under microirrigation, higher salt content can be tolerated in the soil than under sprinkler irrigation without yield reduction. Equation 4 is used to calculate leaching fraction under microirrigation.

$$LF = EC_i / 2\ (\text{Max } EC_e) \qquad (4)$$

Equation 4.

where:

Max EC_e can be found in Table 3.

LF calculated from Equation 4 can be used in Equation 1 to calculate D_d (depth of additional water to be applied).

Under high frequency irrigation (microirrigation) salts that accumulate below the emitters can be almost continuously flushed. When LF > 0.1, it is recommended that additional water is used for flushing to keep salts from concentrating in the plant root zone.

The minimum EC_e is a useful parameter for estimating the effect of microirrigation on crop yield. If EC_i <= min EC_e, there will be essentially no reduction in yield.

Reclamation of Salt-Affected Soils

Reclamation is defined as a procedure required to restore productivity loss of the soil due to severe salinity problems. The only proven solution to a high concentration of soluble salts in a soil profile is leaching. Leaching requires good drainage so that the salts can be removed from the field. Depending on the condition, if the natural drainage is not adequate, artificial drains (surface or subsurface) must be constructed. A general rule is that to remove 80% of soluble salts initially present in a soil profile, the depth of water equal to the depth of this profile must be applied. A reclamation should be done by application of water over the entire area as uniformly as possible through flooding or sprinkling.

References

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Table 3. Specific minimum and maximum balues of EC_e for Various crops.

Crop	EC_e,dS/m Min[1]	Max[2]	Crop	EC_e,dS/m Min[1]	Max[2]
Field crops					
Cotton	7.7	27	Corn	1.7	10
Sugar beets	7.0	24	Flax	1.7	10
Sorghum	6.8	13	Broadbeans	1.5	12
Soybean	5.0	10	Cowpeas	1.3	8.5
Sugarcane	1.7	19	Beans	1.0	6.5
Fruit and nut crops					
Date palm	4.0	32	Apricot	1.6	6
Fig, olive	2.7	14	Grape	1.5	12
Pomegranate	2.7	14	Almond	1.5	7
Grapefruit	1.8	8	Plum	1.5	7
Orange	1.7	8	Blackberry	1.5	6
Lemon	1.7	8	Boysenberry	1.5	6
Apple, pear	1.7	8	Avocado	1.3	6
Walnut	1.7	8	Raspberry	1.0	5.5
Peach	1.7	6.5	Strawberry	1.0	4
Vegetable crops					
Zucchini squash	4.7	15	Sweet corn	1.7	10
Beets	4.0	15	Sweet potato	1.5	10.5
Broccoli	2.8	13.5	Pepper	1.5	8.5
Tomato	2.5	12.5	Lettuce	1.3	8
Cucumger	2.5	10	Radish	1.2	9
Cantaloupe	2.2	16	Onion	1.2	7.5
Spinach	2.0	15	Carrot	1.0	8
Cabbage	1.8	12	Beans	1.0	6.5
Potato	1.7	10	Turnip	0.9	12

after Ayers and Wescott (1985).

[1]Minimum EC_e does not reduce yield.

[2]Maximum EC_e reduces yield to zero.