Soil and Water

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The Key: Accurately Estimating the Water Needed

Even in Drought, Leaching is the Answer to Excessive Soil Salinity

By
Blaine Hanson

When high salinity levels threaten crop growth, leaching – applying extra irrigation water for a short time – can solve the problem by moving salts down past the root zone. With the proper techniques, leaching can be accomplished effectively even when water is in short supply.

The first step in leaching out salts is to determine the *leaching requirement* – the amount of excess water needed to keep the root zone soil salinity at a level the crop can tolerate. The leaching requirement depends on both the crop's tolerance to salinity and on the salinity of the irrigation water.

A publication entitled "Crop Salt Tolerance," from the University of California Cooperative Extension Service Irrigation Series sets out the root zone salinity levels necessary to prevent yield reductions and to limit yield reductions to a given percentage for 34 California crops. The publication is available from the UC Cooperative Extension Office, 241 Veihmeyer Hall, UC Davis 95616.

With that information, Figure 1 on page 5 can be used to find the leaching requirement. Figure 1 shows the relationship between the salinity of the irrigation water (described by its electrical conductivity, or *ECi*) and the average root zone salinity (described by the EC of the saturated extract, or *ECe*). The leaching requirement can be estimated by drawing a horizontal line through the allowable ECe for the crop and a vertical line through the ECi.

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How to Find the Application Rate of Low-Volume Irrigation Systems

By
Larry Schwankl

Irrigation scheduling information and crop water use data is usually presented in inches per day, while discharge from low-volume emitters is measured in gallons per hour. How, then, can one determine the application rate of low-volume irrigation systems? Follow the steps below to figure the application rate for drip and micro-sprinkler emitters.

How long drip and micro-sprinklers should operate depends on the crop water use and the application rate of the emission device. The first step in determining the required operating time is to convert the crop water use information (usually in inches per day) to gallons per day of plant water use. The following formula can be used:

Water use by plant (gallons/day)	=	Plant spacing (ft^2)	x	Crop water use (inches/day)	x 0.623

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Drought Tips

Deciding How Much to Plant During a Drought

By
Richard L. Snyder

The most effective response to a severe drought is usually to reduce planted acreage. If a crop's net application requirement, the application efficiency of the irrigation system, and the quantity of irrigation water available from a water district or wells are known, the amount of acreage to plant can be determined by calculating a water balance.

In a water balance, the total water additions (from all sources) must equal the total water losses. One component of the water balance is the required gross application amount (or applied water), which can be determined if the other components are known. Then, if one knows the quantity of water available for irrigation, the acreage to plant can be calculated.

Water Balance Calculations

Sources of water for a crop include (1) pre-season usable soil water, (2) water tables, (3) fog interception, (4) effective rainfall, and (5) applied irrigation water. Losses of water from an irrigated crop include crop water use (crop evapotranspiration) and irrigation application losses. Since the total losses equal the total additions, the following equation applies:

$$AL + ETc = AW + PW + WT + F + ER \quad (1)$$

where

AL = application losses
ETc = crop evapotranspiration
AW = gross application (applied water)
PW = pre-season stored soil water
F = fog interception
ER = effective rainfall

Rearranging equation 1, the requirement for applied water is calculated as:

$$AW = ETc - (PW + WT + F + ER) + AL \quad (2)$$

or as:

$$AW = NA + AL \quad (3)$$

where NA = ETc - (PW + WT + F + ER) is the net application requirement. The net application requirement is calculated from estimated water balance parameters, and the application losses are approximated using a seasonal estimate of application efficiency.

Application efficiency is defined as the ratio of applied water to the amount of applied water stored for use by the crop. If the irrigations are well managed, the application efficiency will approximately equal the net application requirement divided by the applied water. Therefore, the application efficiency (AE) is estimated as:

$$AE = NA + AW \quad (4)$$

and AW is calculated using the equation:

$$AW = NA + AE \quad (5)$$

From Equation 3, the application losses equal the difference between applied water and the net application requirement:

$$AL = AW - NA \quad (6)$$

and using Equations 5 and 6, the application losses are calculated as:

$$AL = (NA + AE) - NA \quad (7)$$

Pre-Season Usable Soil Water

Pre-season usable soil water is calculated as the difference between the pre-season water content within the full crop root zone and the expected end-of-season soil water content. Pre-season soil water content can be measured or estimated. The expected end-of-season soil water content depends on district delivery constraints, crop factors, irrigation method, soil considerations, and labor. Generally, the end-of-season soil water content will be greater than 75 percent of field capacity. Therefore, if field capacity is 10 inches, the end- of-season soil water content is typically between 7.5 and 10 inches. Crops that are sensitive to water stress end the season with a water content closer to field capacity. Also, fields immediately replanted to another crop often end with a higher final water content. When a field is not planted during the rainy season, a lower end-of-season soil water content is possible.

Water Table Contributions

Although the amount of water provided is difficult to estimate, upward movement of water from water tables can

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APPLICATION RATES, Continued from page 1

For example:

Tree crop spacing = 20 ft. x 20 ft. = 400 ft²
Crop water use = 0.3 inches/day
Water use by the plant = 400 ft² x 0.3inches/day x 0.623
= 75 gallons/day

Step 3 is to determine the operating time of the irrigation system in hours per day. This requires using the crop water use (from Step 1) and the application rate (from Step 2). The following formula can be used (or see Table 2, page 6):

Hours of operation per day (hours/day) = crop water use (gallons/day) / application rate (gallon/hour)

Crop water use (inches / day)

Crop Spacing (feet²)	0.05	0.1	0.15	0.2	0.25	0.3	0.35	0.4
100	3	6	9	12	16	19	22	25
200	6	12	19	25	31	37	44	50
400	12	25	37	50	62	75	87	100
600	19	37	56	75	93	112	131	150
800	25	50	75	100	125	150	174	199
1000	31	62	93	125	156	187	218	249
1200	37	75	112	150	187	224	262	299
1400	44	87	131	174	218	262	305	349
1600	50	100	150	199	249	299	349	399
1800	56	112	168	224	280	336	392	449
2000	62	125	187	249	311	374	436	498
2200	69	137	206	274	343	411	480	548
2400	75	150	224	299	374	449	523	598

Table 1. Crop water use (gallons / day) for various plant spacings and crop water use (inches/day)

Table 1, above, provides a short-hand method of obtaining the same information.

Step 2 in determining the required operating time is to find the application rate of the irrigation system in gallons per hour. For both drip emitters and micro-sprinklers, this requires determining the number of emission devices per plant and the discharge rate per emission device (gallons/hour/emitter):

Application rate (gallons/hour) = Number of emission devices x Discharge rate per emission device (gallons/hour/emitter)

For example:

Number of emitters = 4 per tree
Discharge rate per emitter = 1 gallon/hour
Application rate = 4 emitters/tree x 1 gallon/hour per emitter
= 4 gallons/ hour

Discharge rate per micro-sprinkler = 12 gallons/hour
Application rate = 1 micro-sprinkler/tree x 12 gallons/hour per microsprinkler (gallons/hour)
= 12 gallons/hour

For example:

Drip emitters:
Crop water use (gallons/day = 75 gallons/day (Step 1)
Application rate (gallons/hour) = 4 gallons/hour (Step 2)

Hours of operation per day = 75 gallons/day/4 gallons/hour
= 18.8 hours/day

Micro-sprinklers:
Crop water use (gallons/day) = 75 gallons/day
Application rate (gallons/hour) = 12 gallons/day

Hours of operation per day (hours/day) = 75 gallons/day/12 gallons/hour
= 6.3 hours/day

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LEACHING, Continued from page 1

The leaching requirement is the point at which the two lines intersect.

Assessing Salinity Hazards
Conventional Irrigation

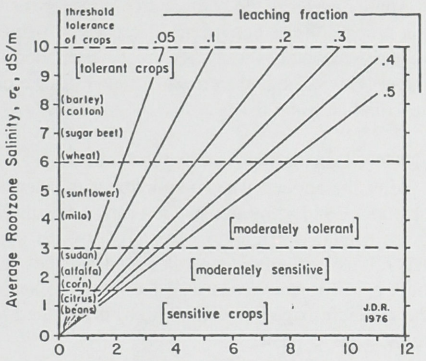

Figure 1. Relationship between average root zone salinity, irrigation water salinity, and leaching requirement / fraction.

(Source : **J.D. Rhoades, "Using saline waters for irrigation."** ***Proceedings of the International Workshop on Salt-Affected Soils of Latin America, International Society of Soil Science,*** **October 23-30, 1983. Maracay, Venezuela.)**

EXAMPLE : Estimate the leaching requirement for cotton irrigated with water having an ECi of 0.7 dS/m.

To prevent yield reduction, the maximum root zone ECe for cotton is 7.7 dS/m (from "Crop Salt Tolerance"). For an ECe of 7.7 dS/m and an ECi of 0.7 dS/m, the leaching requirement is about 2 percent of the applied irrigation water (from Figure 1).

This approach can be used to estimate the leaching requirements for much of the San Joaquin Valley. The normal ECi of surface irrigation water in the valley is 0.3 to 0.5 dS/m. For ECe's ranging up to 8 or 9 dS/m (barley, cotton), Figure 1 shows a leaching requirement of less than 0.05, or 5 percent of the applied irrigation water. Broccoli, tomatoes, and cantaloupe may have a leaching requirement of 2 to 3 percent, while the leaching requirement for beans is about 5 percent. Since frequently deep percolation caused by over-irrigation and by non-uniform water applications exceeds these leaching requirements, salinity is not likely to be excessive where surface irrigation water is used unless saline high water tables are present.

Where disposal of subsurface drainage water is a problem, it may be desirable to allow a slight yield reduction and to use a smaller leaching requirement to reduce the volume of drainage water to be disposed.

The technique given here for estimating the leaching requirement assumes that the applied irrigation water is the only source of salt and that a long-term equilibrium exists between root zone salinity and irrigation water salinity. If part of the crop's water use comes from saline groundwater, the above approach will underestimate the leaching requirement. Also, significant changes in soil salinity levels over time – as may occur with a saline high water table – can cause errors in estimating the leaching requirement.

The leaching requirements calculated from this procedure are meant to be guidelines only. The actual leaching requirement depends on conditions specific to a given site and on how closely the site conditions match the assumptions used in this method as to patterns of water extract by plants, plant response to patterns of root zone salinity, and leaching efficiency.

Leaching Fraction

Figure 1 can also be used to estimate the *leaching fraction*, which is the actual amount of excess water applied. The leaching fraction must at least equal the leaching requirement if soil salinity is not to exceed what the crop will tolerate.

Step 1. Obtain at least four soil samples at varying depths, with each sample representing about one-quarter of the root zone.

Step 2. Measure the ECe of the saturated extract.

Step 3. Calculate the average ECe of the root zone. Use a linear average for conventional irrigation.

Step 4. Measure the ECi of the irrigation water.

Step 5. Find the intercept of a horizontal line drawn through the ECe and a vertical line drawn through the ECi. The intercept is the leaching fraction.

EXAMPLE: What is the leaching fraction for the following root zone salinity levels when the EC of the irrigation water is 1 d S/ m?

Depth Interval (feet)	EC (dS/m)
0 - 1	1.0
0 - 2	3.6
2 - 3	6.2
3 - 4	9.4

The average root zone salinity is (1.0 + 3.6 + 6.2 + 9.4) /4 = 5.0 dS/m. From Figure 1, for an ECe of 5 dS /m and an ECi of 1 dS /m, the leaching fraction is about 4 percent.

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LEACHING, *Continued from page 5*

However, when salt distribution changes with depth, as in Table 2, below, caution must be exercised.

Depth Interval (feet)	ECe (dS/m)
0 - 1	2.1
1 - 2	1.4
2 - 3	0.9
3 - 4	0.8

Table 2. Distribution of salts with depth in tomato crop. ECi = 0.2 dS / m.

Under the procedure described above, the leaching fraction under these conditions would be 1 to 2 percent. But here salinity is highest at the surface, suggesting that no leaching is occurring -- since if leaching were adequate, soil salinity would be lowest near the surface.

Note : An article forthcoming in the Fall 1991 issue of* Soil and Water *will discuss reclaiming saline- and boron-affected soils through leaching.

HOW MUCH TO PLANT (Continued from page 3)

contribute to crop water needs. During a drought, water tables often drop and thereby contribute less. At this time, information available on water table contribution is site-specific and has been estimated from past experience.

Fog Interception

In foggy areas, water intercepted by plants from the fog can provide some of a crop's water needs. Although daily amounts from fog may be small, the cumulative effect can be significant. Fog is intercepted by and coats the plants, and evaporation of the intercepted water substitutes for water removal from the soil. The amount of water supplied by fog is estimated using a diurnal ETc curve and the approximate time of day fog dries off the crop.

Effective Rainfall

Effective rainfall occurs during the growing season and either coats the plants or is stored in the crop root zone where it contributes to crop water use. Surface runoff and percolation of excess water below the crop's root zone are not effective rainfall. Surface runoff is difficult to estimate, but is generally small during the main growing season of most California crops. Deep percolation of rainfall depends on the soil water content before the rainfall and the amount of rainfall that infiltrates the soil. The effective rainfall cannot be greater than the soil water depletion before the rainfall, so the management allowable depletion -- the soil water depletion level a grower decides not to exceed between irrigations -- provides an upper limit for effective rainfall. For example, if a grower never allows more than two inches of soil water depletion between irrigations, the effective rainfall cannot be greater than two inches.

Applied Water (or Gross Application)

Applied water is the main source of water for most California crops. When determining acreage to plant, the objective is to use a water balance to calculate the applied water requirement. This value is then used with an estimate of the available irrigation water to determine the acreage.

Calculating Acreage to Plant

After the applied water requirement is determined using Equations 2 and 7, the area to plant can be calculated by dividing the available irrigation water (IW) by the applied water (AW). If the applied water is calculated in inches, divide the amount by 12 to convert to acre-feet per acre and then divide the available irrigation water (IW) by the applied water to determine acres to plant.

$$ACRES = IW + (AW + 12) \quad (8)$$

Sample Calculations:
Given the following data:
Crop evapotranspiration (ETc) = 27 inches
Pre-season usable water (PW) = 4 inches
Fog interception (F) = 1 inch
Effective rainfall (ER) = 2 inches
Water table contribution (WT) = 0 inches
Application efficiency (AE) = 80 percent
Irrigation water (IW) available = 1000 acre feet,
Calculate the acreage to plant.

Step 1: Net application
NA = ETc - (PW + WT + F + ER)
NA = 27 - (4 + 0 + 1 + 2) = 20 inches

Step 2: Application losses
AE = 80% = 0.80
AL = (NA + AE) - NA
AL = (20 + 0.80) - 20 = 5 inches

Step 3: Applied water (or gross application)
AW = NA + AL
AW = 20 + 5 = 25 inches

Step 4: Acres to plant
AW = 25 inches + 12 inches per foot = 2.083 acre-feet per acre
Acres = IW+ AW
Acres = 1000 + 2.083 = 480 acres

APPLICATION RATES, Continued from page 4

Table 2. Hours of operation per day for various application rates (hours/day) and crop water use (gallons/day)

Crop Water Use (gallons/ day)	Application rate (gallons/ hour)										
	1	2	4	6	8	10	12	14	16	18	20
5	5.0	2.5	1.3								
10	10.0	5.0	2.5	1.7	1.3	1.0					
15	15.0	7.5	3.8	2.5	1.9	1.5	1.3	1.1			
25		12.5	6.3	4.2	3.1	2.5	2.1	1.8	1.6	1.4	1.3
50			12.5	8.3	6.3	5.0	4.2	3.6	3.1	2.8	2.5
75			18.8	12.5	9.4	7.5	6.3	5.4	4.7	4.2	3.8
100				16.7	12.5	10.0	8.3	7.1	6.3	5.6	5.0
125				20.8	15.6	12.5	10.4	8.9	7.8	6.9	6.3
150					18.8	15.0	12.5	10.7	9.4	8.3	7.5
175					21.9	17.5	14.6	12.5	10.9	9.7	8.8
200						20.0	16.7	14.3	12.5	11.1	10.0
225						22.5	18.8	16.1	14.1	12.5	11.3
250							20.8	17.9	15.6	13.9	12.5
275							22.9	19.6	17.2	15.3	13.8
300								21.4	18.8	16.7	15.0
325								23.2	20.3	18.1	16.3
350									21.9	19.4	17.5
375									23.4	20.8	18.8
400										22.2	20.0
425											21.3
450											22.5
475											23.8

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