Controlling Soil Salinity

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Where Do Salts in the Soil Come From?

- Irrigation water
- Upward flow from a saline, shallow water table
- Fertilizers

Salinity - Total Dissolved Salts (TDS)

- Calcium
- Magnesium
- Sodium
- Chloride
- Sulfate
- Bicarbonate/carbonate
- Minor - nitrate, potassium

Electrical Conductivity (EC)

- Measure of the ability of a solution to conduct electricity
- The larger the salt concentration, the larger the EC
  - Doubling the concentration does not double the EC
- Units of EC
  - millimhos per centimeter - mmhos/cm
  - micromhos per centimeter -μmhos/cm
  - decisiemens per meter - dS/m (equals mmhos/cm)

TDS (ppm) = K x EC (dS/m, mmho/cm)

- Generalized
  - K = 640: EC less than 5 dS/m
  - K = 800: EC more than 5 dS/m
- San Joaquin Valley Drainage Water
  - K = 740: EC less than 5 dS/m
  - K = 840:EC between 5 and 10 dS/m
  - K = 920: EC greater than 10 dS/m
- Santa Maria Valley
  - K = 740

Measuring soil salinity

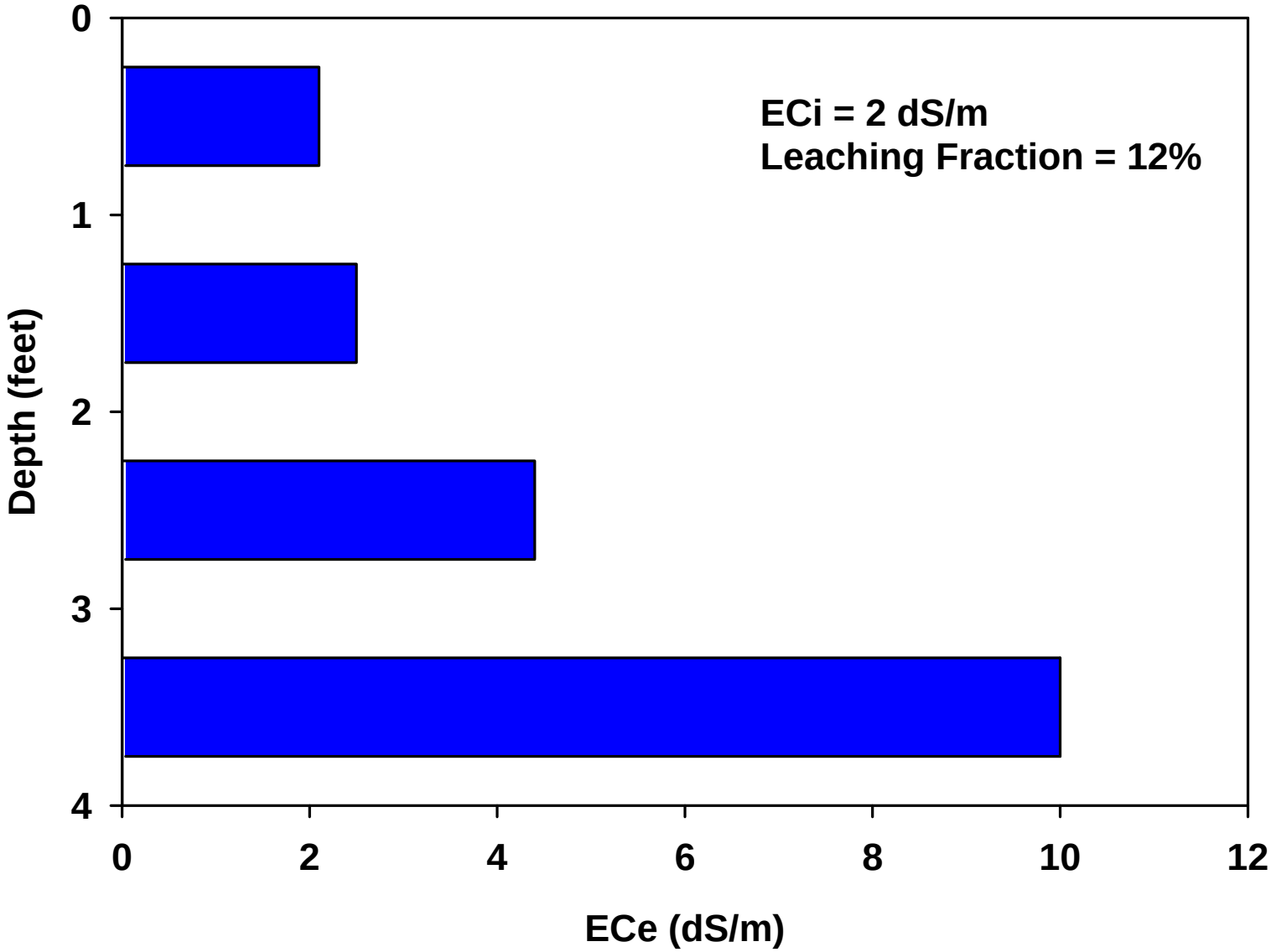
- EC of saturated extract (ECe)
  - Collect soil samples with depth in the root zone
  - Dry the soil and then grind it
  - Add distilled water until the soil is saturated
  - Extract the solution from the soil with a vacuum extraction apparatus
  - ECe can be related to crop tolerance values
- Soil EC expressed as a 1:1, 1:5, or 1:10 soil/water ratios
  - Monitor soil salinity over time
  - Not very useful for assessing soil salinity impact on crop yield

Leaching

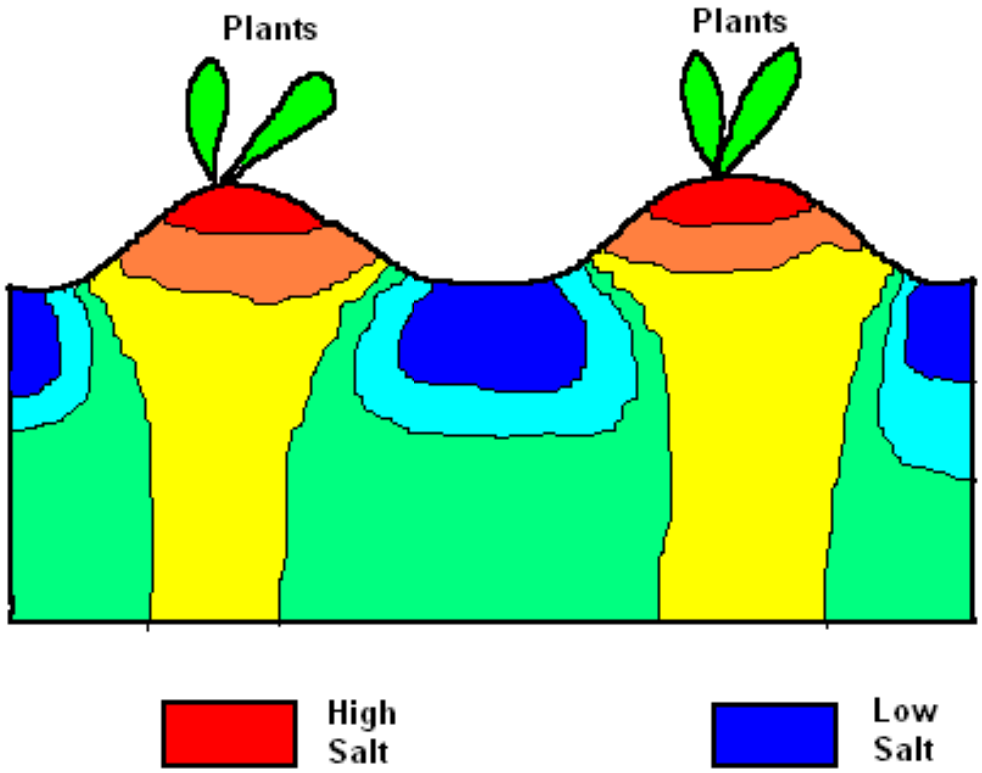
- Leaching - process of applying irrigation water in excess of soil moisture depletion to flush salt from the root zone. Excess water percolates below the root zone carrying the salt with it.
- Leaching fraction – actual percentage of the applied or infiltrated water that percolates below the root zone
- Leaching requirement - percentage of applied or infiltrated below the root zone needed to maintain soil salinity at the threshold soil salinity
- Leaching fraction should exceed leaching requirement

Salt distributions in soil profile: well-drained conditions

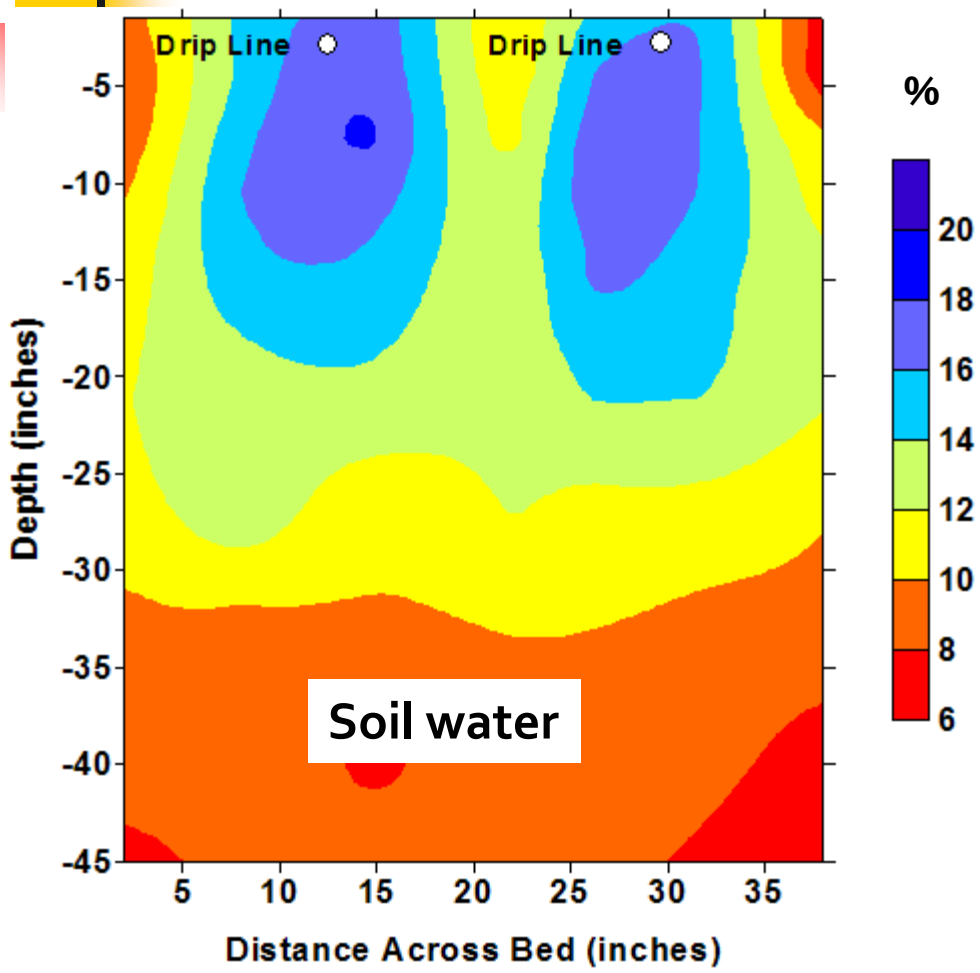
Soil salinity with depth

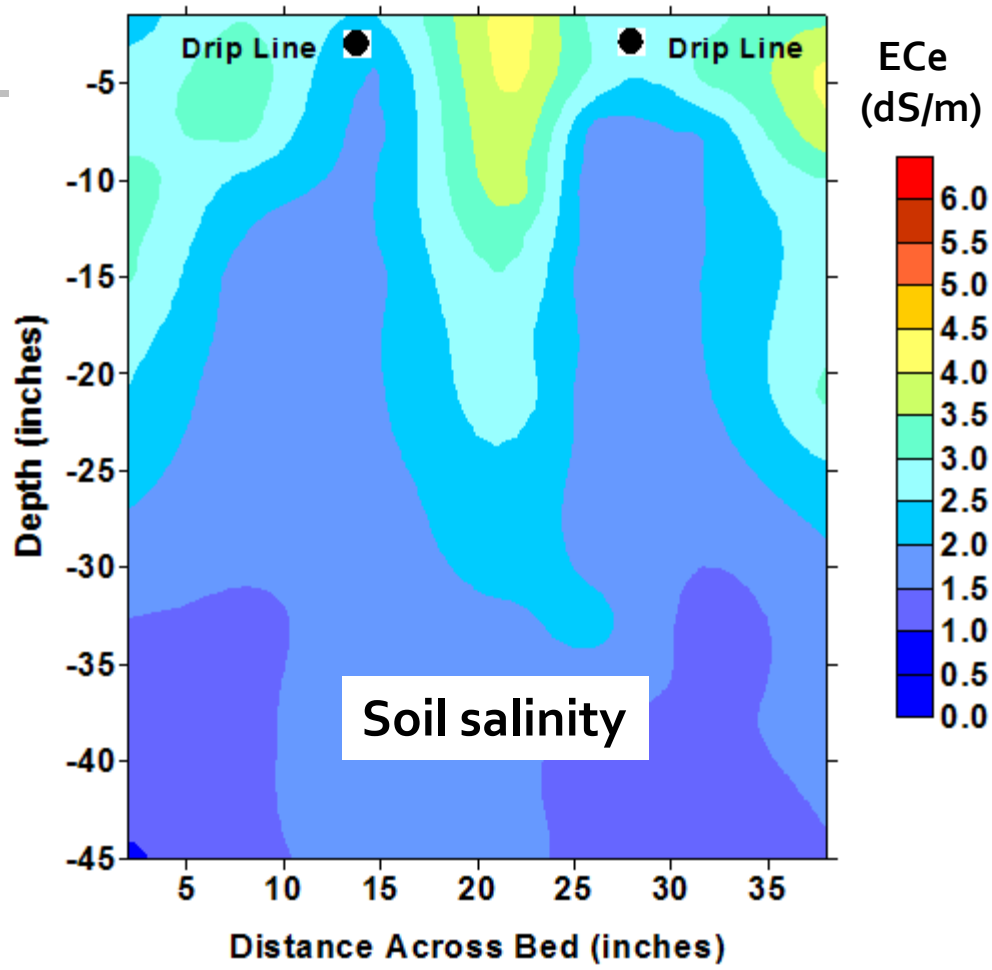


Furrow irrigation

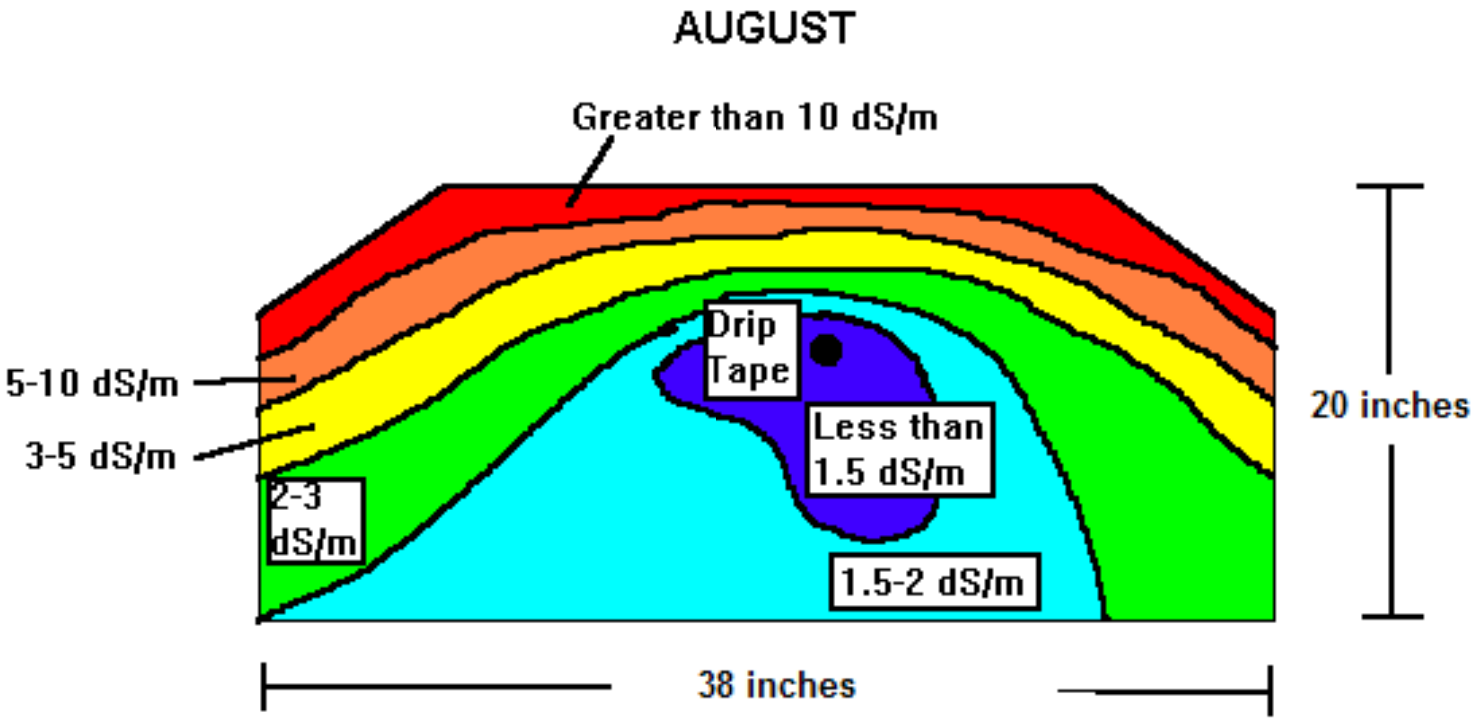


Surface drip irrigation (ECi = 1.5 – 2.0 dS/m



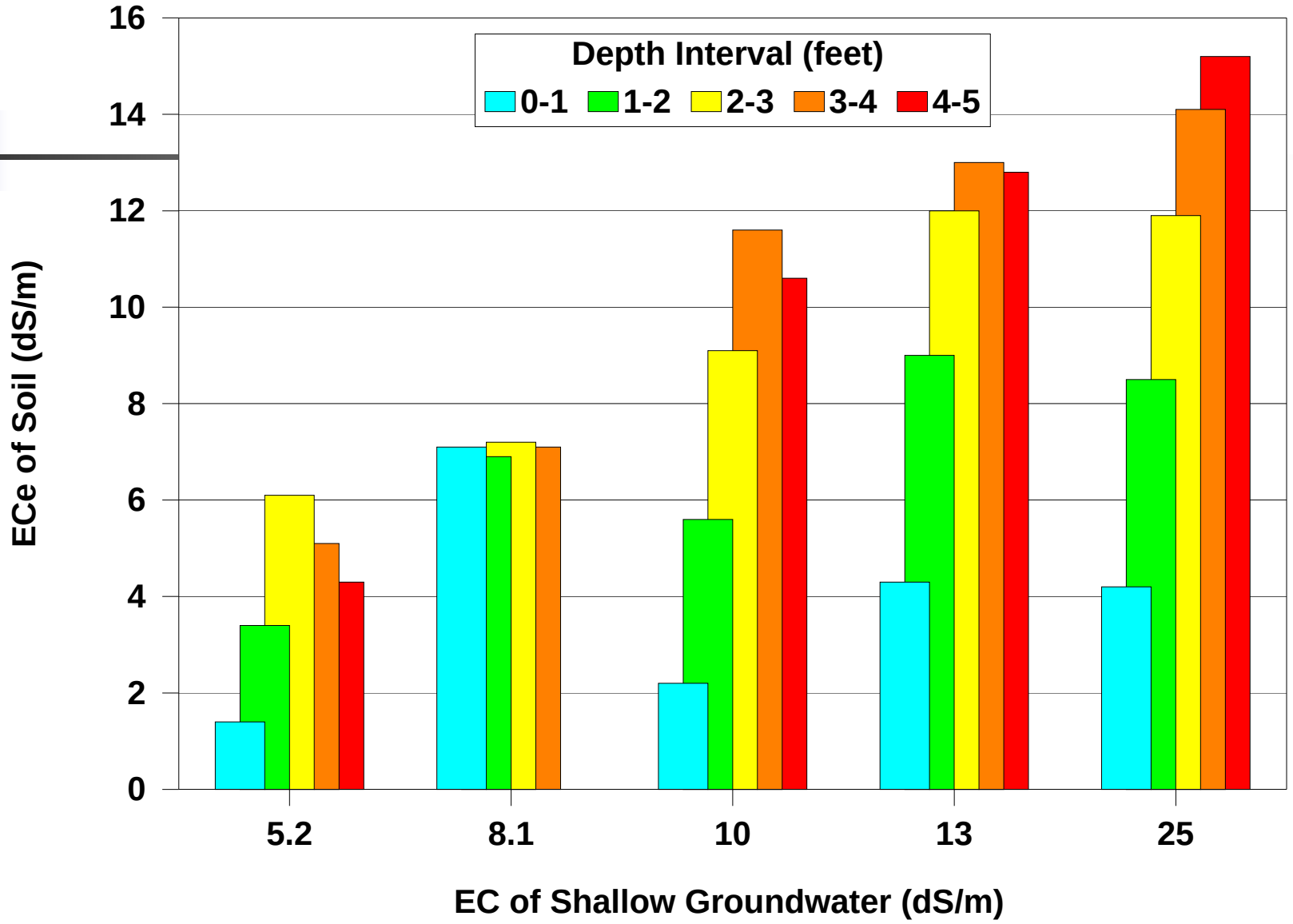


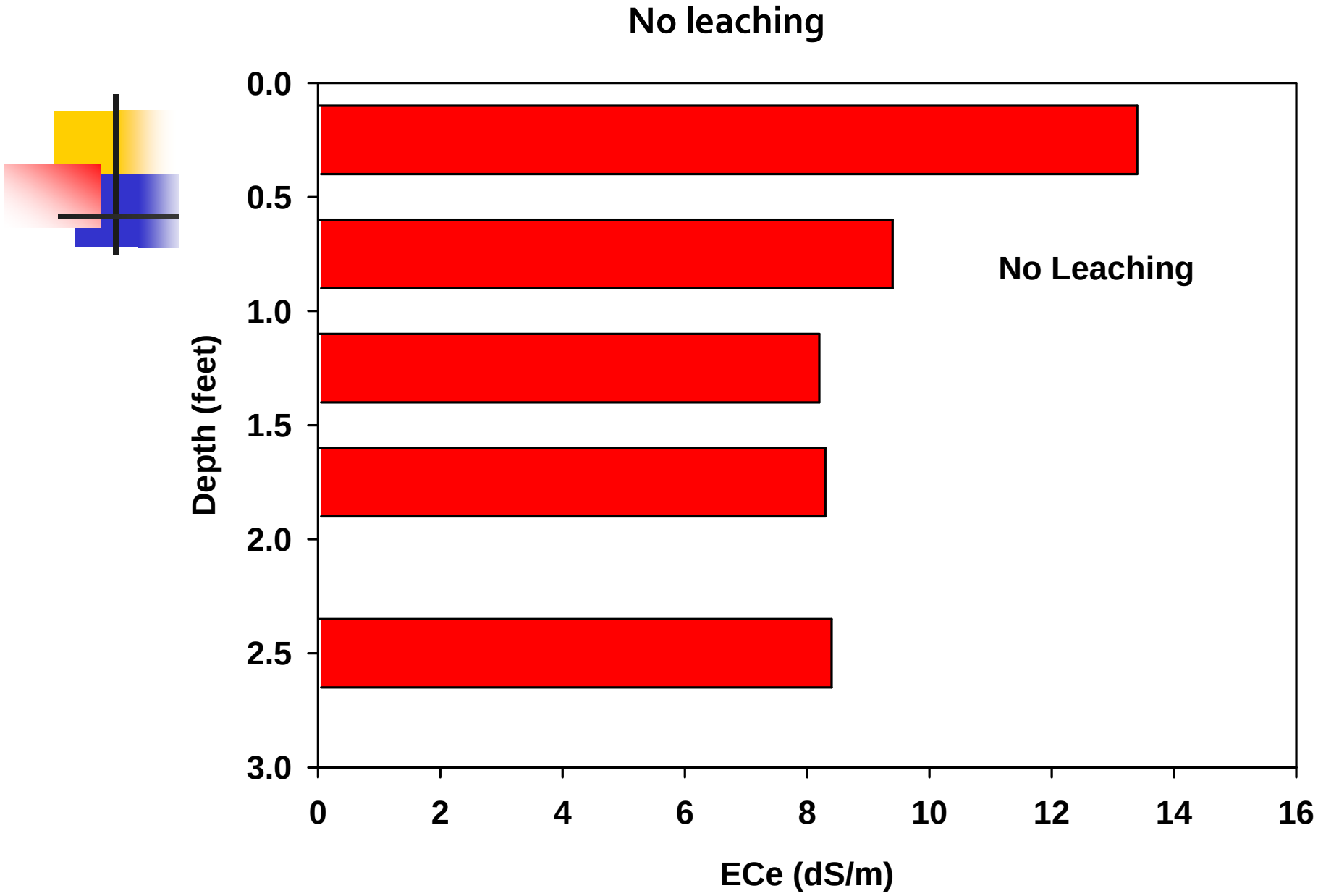
Subsurface drip irrigation (ECi = 2 dS/m)



Salt distributions in soil profile: saline shallow groundwater conditions

Effect of salinity of shallow groundwater

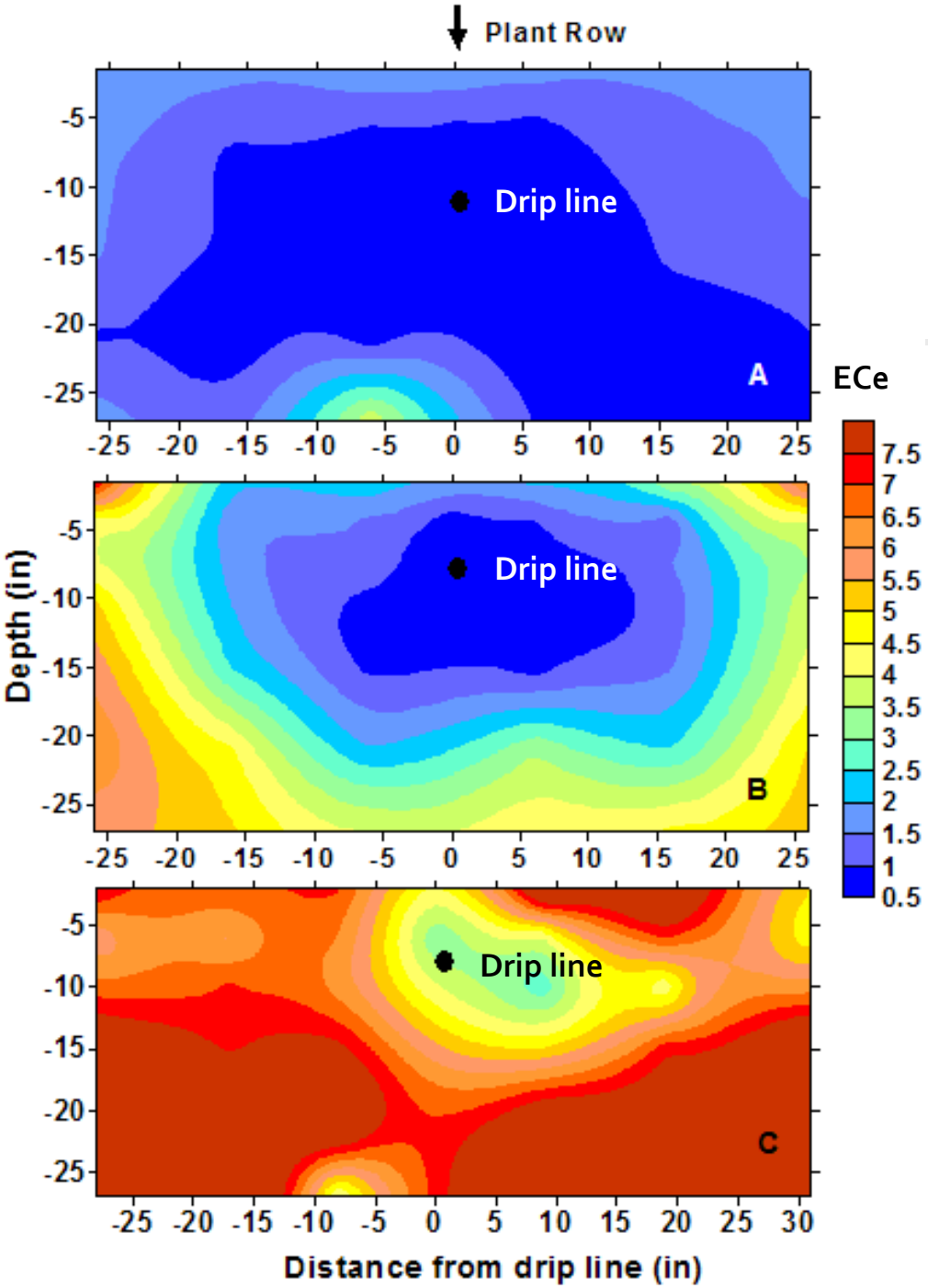



No leaching
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Depth (feet)
No Leaching
0
2
4
6
8
10
12
14
16
ECe (dS/m)

Factors affecting soil salinity with drip irrigation under saline shallow groundwater conditions

- Depth to shallow groundwater
- Salinity of shallow groundwater
- Irrigation water salinity
- Amount of applied water
- Location of drip line relative to plant row
- Soil type

Localized leaching around drip lines



ECi = 0.3 dS/m
ECgw = 8-11 dS/m
GW depth = 6 feet

ECi = 0.3 dS/m
ECgw = 5-7 dS/m
GW depth = 2-3 feet

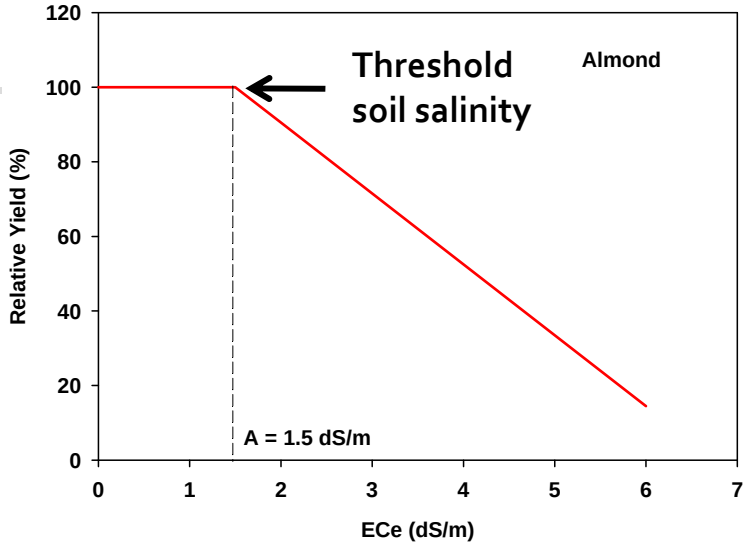
ECi = 1.1 dS/m
ECgw = 9-16 dS/m
GW depth = 2-3 feet

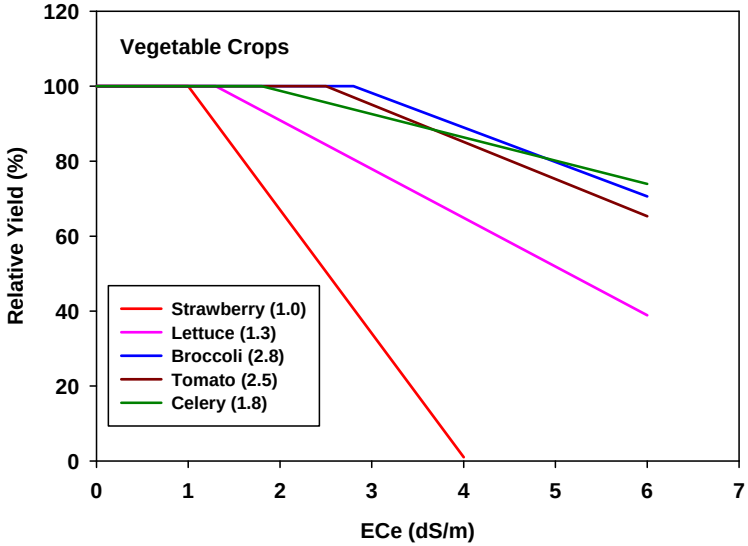
Summary

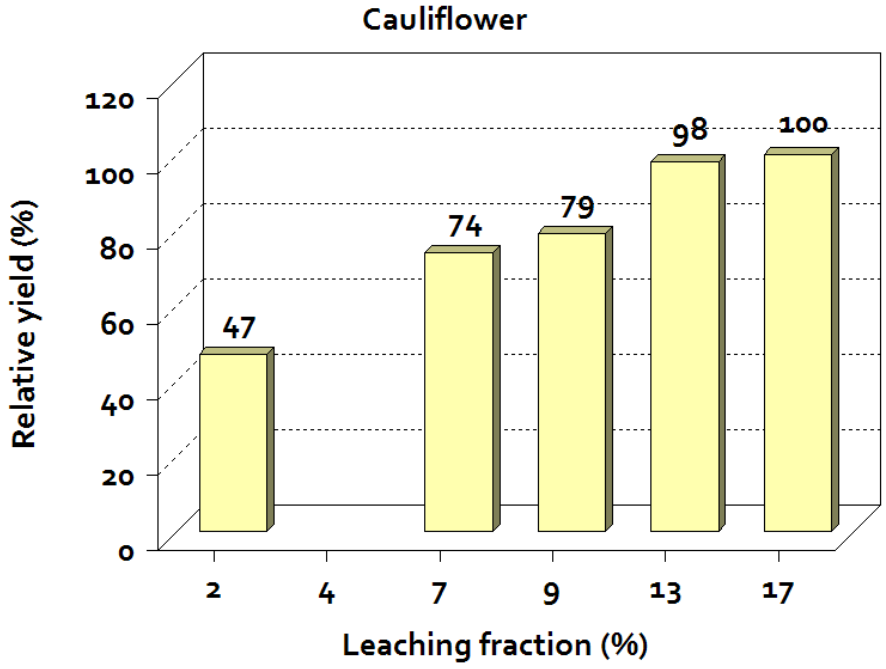
- Well-drained soil profile
  - Soil salinity near surface – irrigation water salinity
  - Soil salinity at deeper depths – irrigation water salinity, leaching fraction
- Saline shallow groundwater conditions
  - Soil salinity near surface – irrigation water salinity
  - Soil salinity at deeper depths – irrigation water salinity, groundwater salinity, leaching fraction?
- Drip irrigation
  - Small levels of soil salinity near drip lines - highly concentrated leaching
  - Salinity increases with horizontal distance from drip line - leaching decreases
  - High salinity levels midway between drip lines - little or no leaching
  - Salt accumulates above buried drip lines - no leaching

Controlling root zone soil salinity

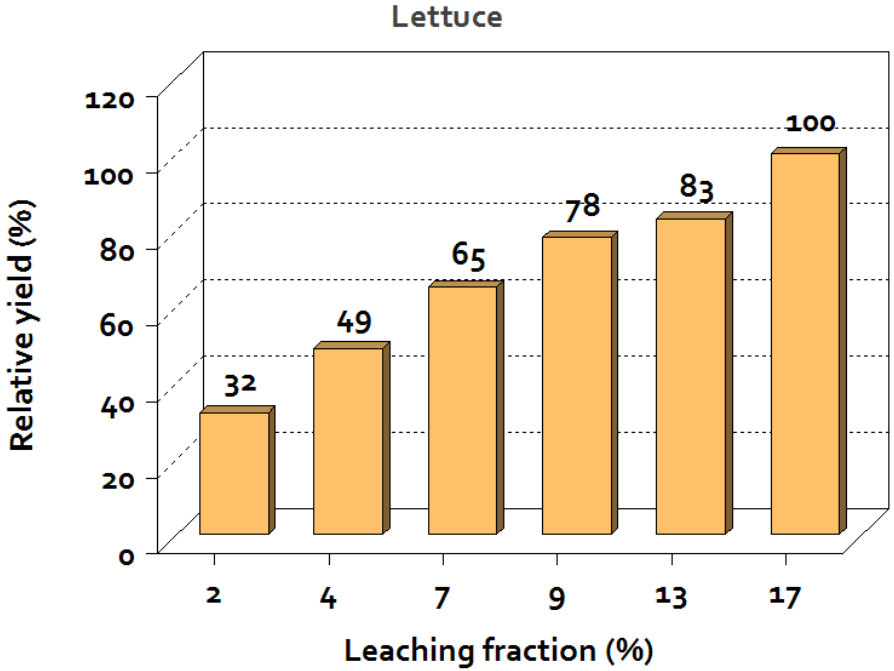
- Objective: reduced or maintain soil salinity at values equal to or less than the threshold soil salinity
- Key principle: apply sufficient water to leach salt from the root zone







ECi = 2.1 dS/m



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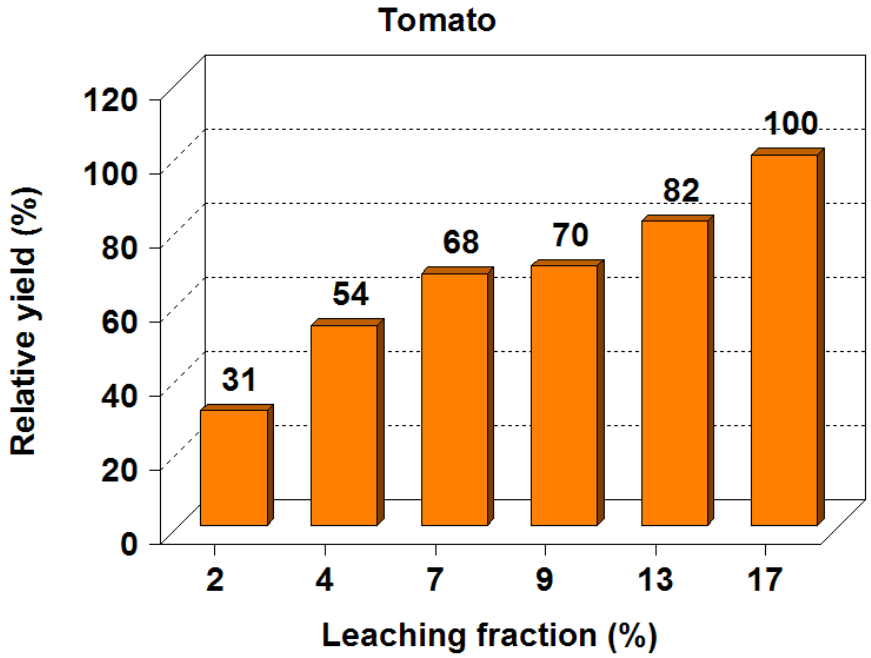

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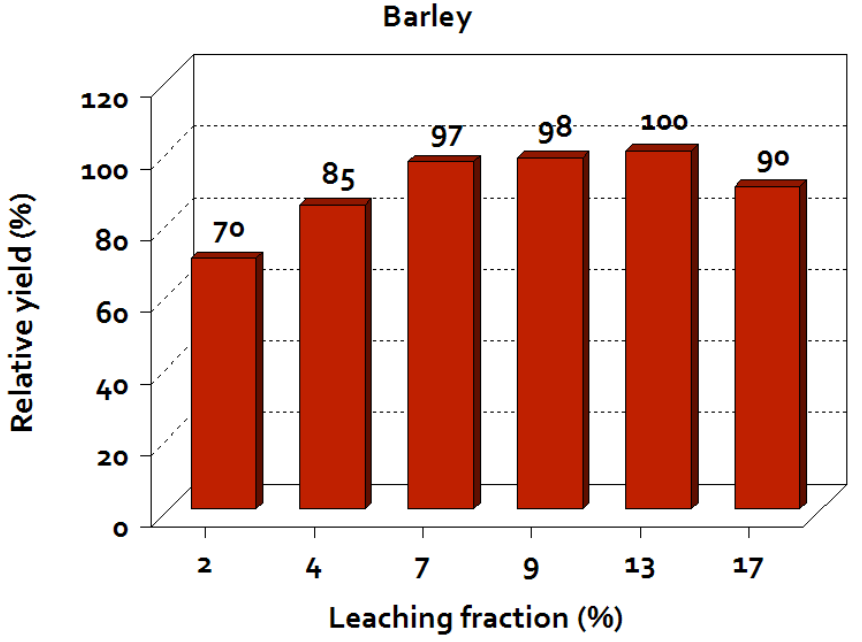
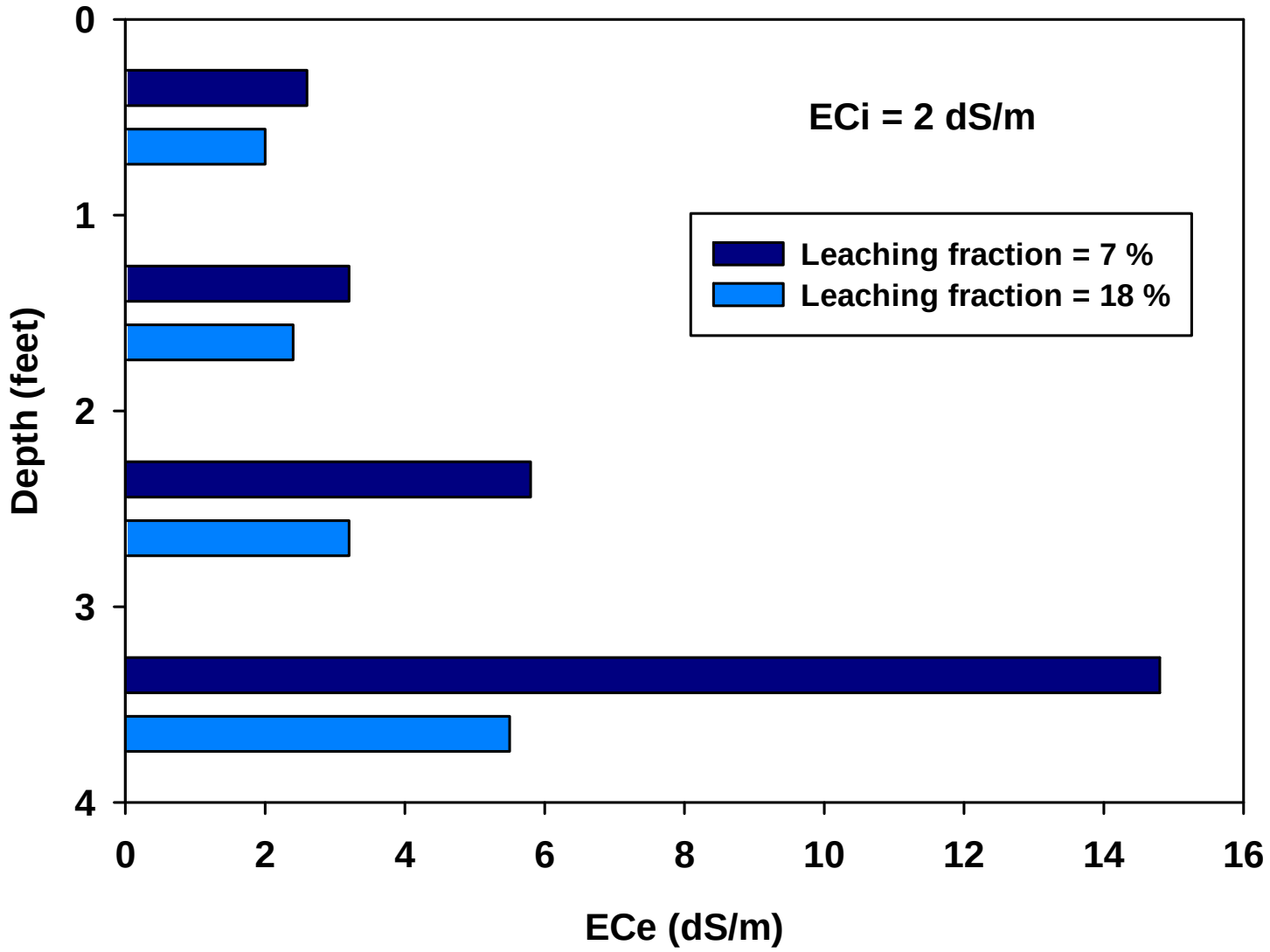


ECi = 2.1 dS/m

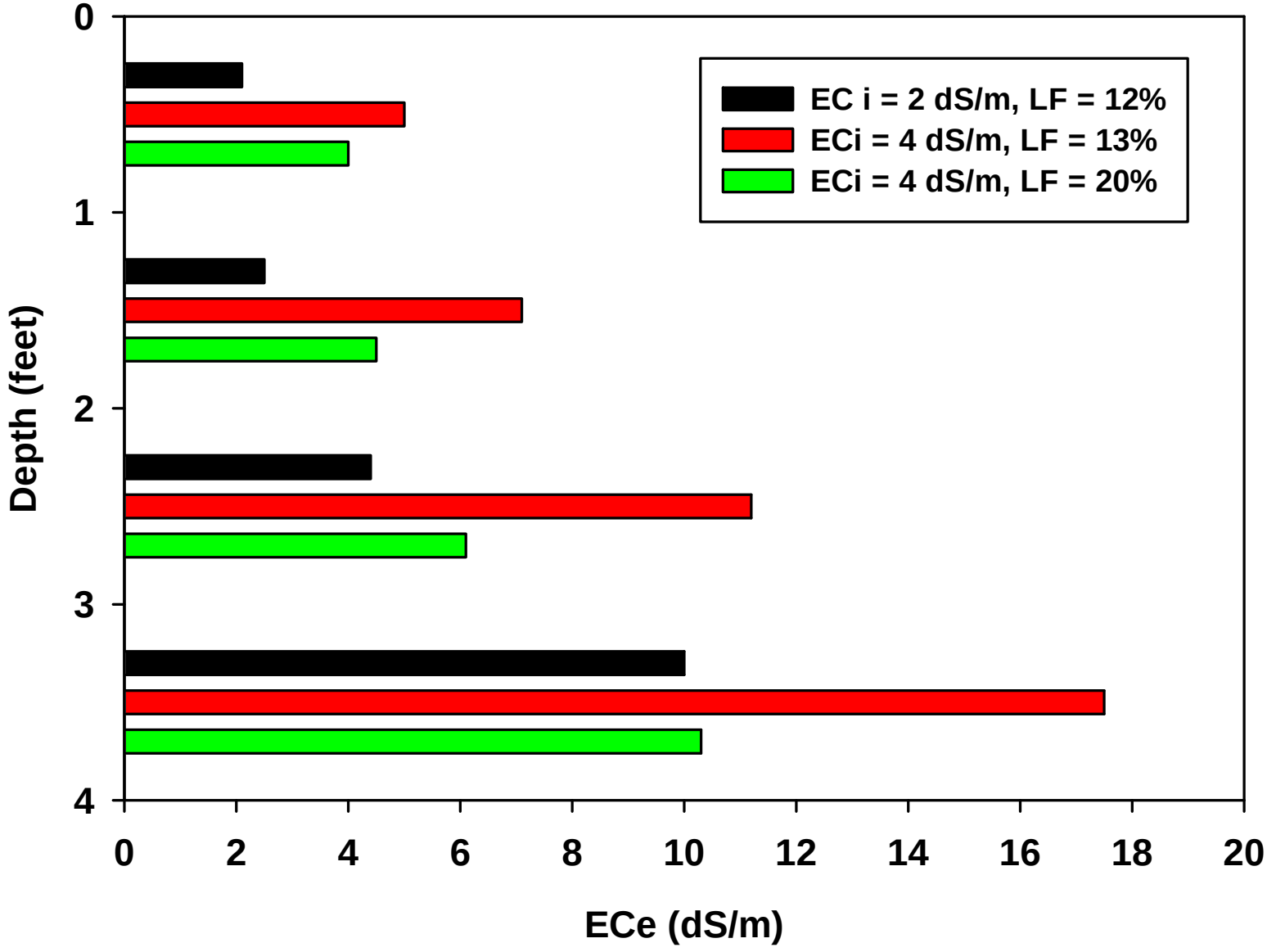
Types of leaching

- Continuous
  - Maintain soil salinity at a more or less constant level
  - Reduction in infiltration rate over time may limit opportunities for continuous leaching
  - Drip irrigation
- Periodic
  - Periodic leaching to reduce accumulated salts in the soil to an acceptable level
  - Pre-plant irrigation
  - Furrow, flood, sprinkle, drip

Effect of leaching fraction (well-drained soil)



Effect of irrigation water salinity and leaching fraction (well-drained soil)

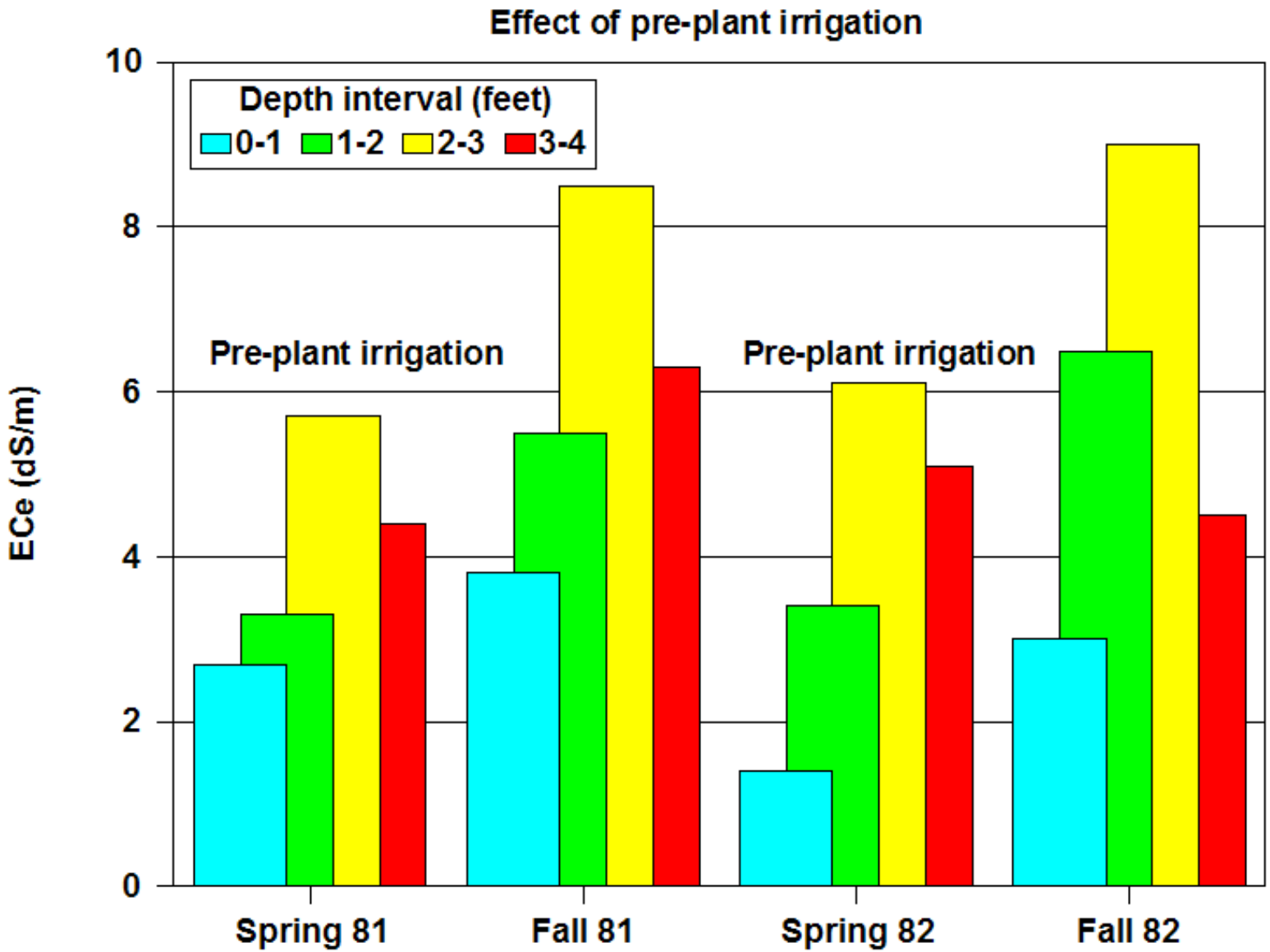


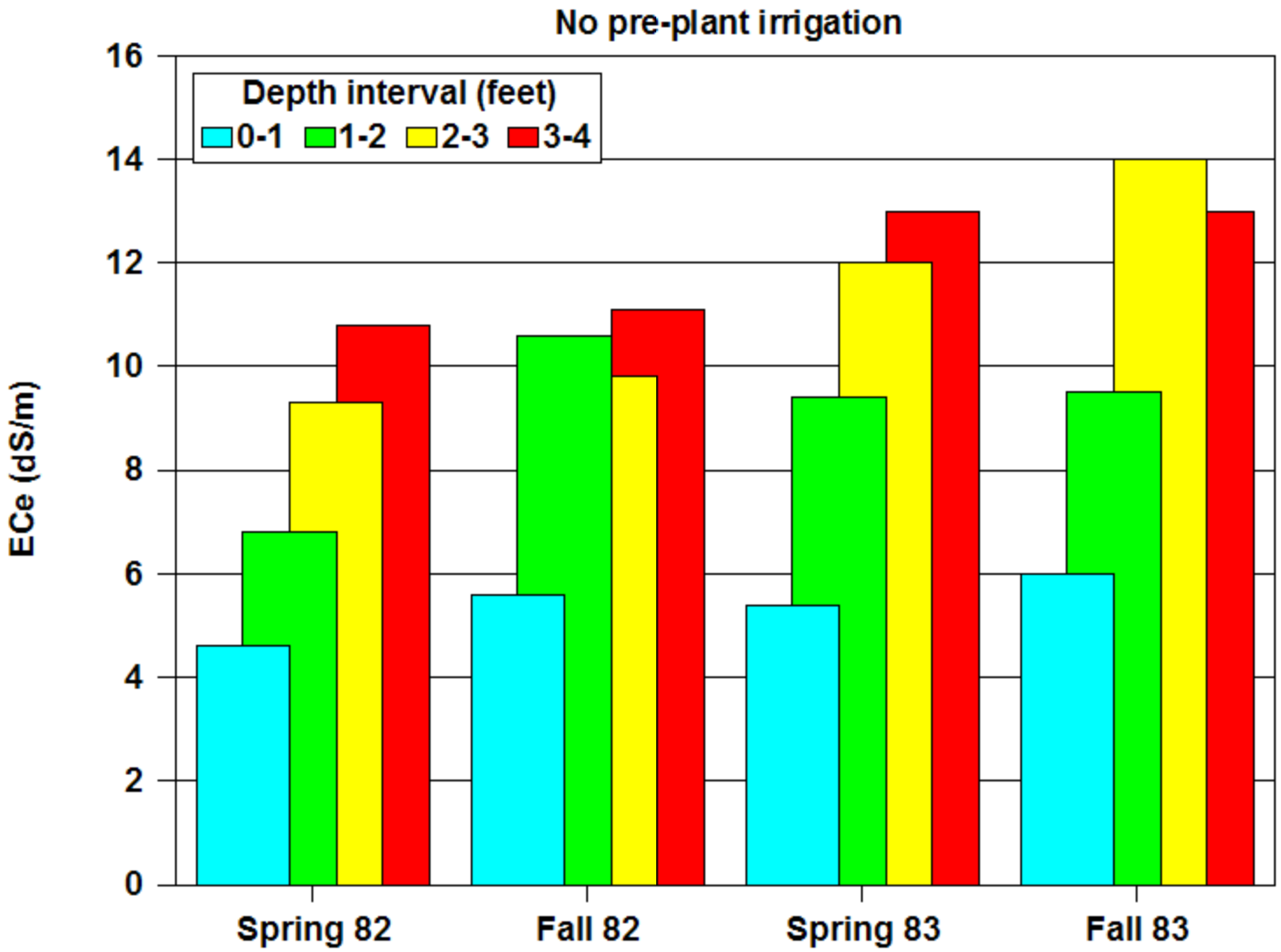
Leaching under saline shallow groundwater conditions

- No subsurface drainage systems
- Shallow soil profile due to saline shallow groundwater
- Careful irrigation water management
- Periodic leaching for furrow, flood, and sprinkle irrigation (pre-plant irrigation)
- Continuous leaching – drip irrigation

Periodic leaching – shallow ground water conditions

- Objective
  - Return fall soil salinity levels to spring levels
  - Replenish fall soil moisture depletion
- Pre-plant irrigation
- Leaching – apply about 1 inch of water per foot of soil to be leached after replenishing any soil moisture depletion


Effect of pre-plant irrigation
Depth interval (feet)
0-1
1-2
2-3
3-4
Pre-plant irrigation
Pre-plant irrigation
ECe (dS/m)
0
2
4
6
8
10
Spring 81
Fall 81
Spring 82
Fall 82

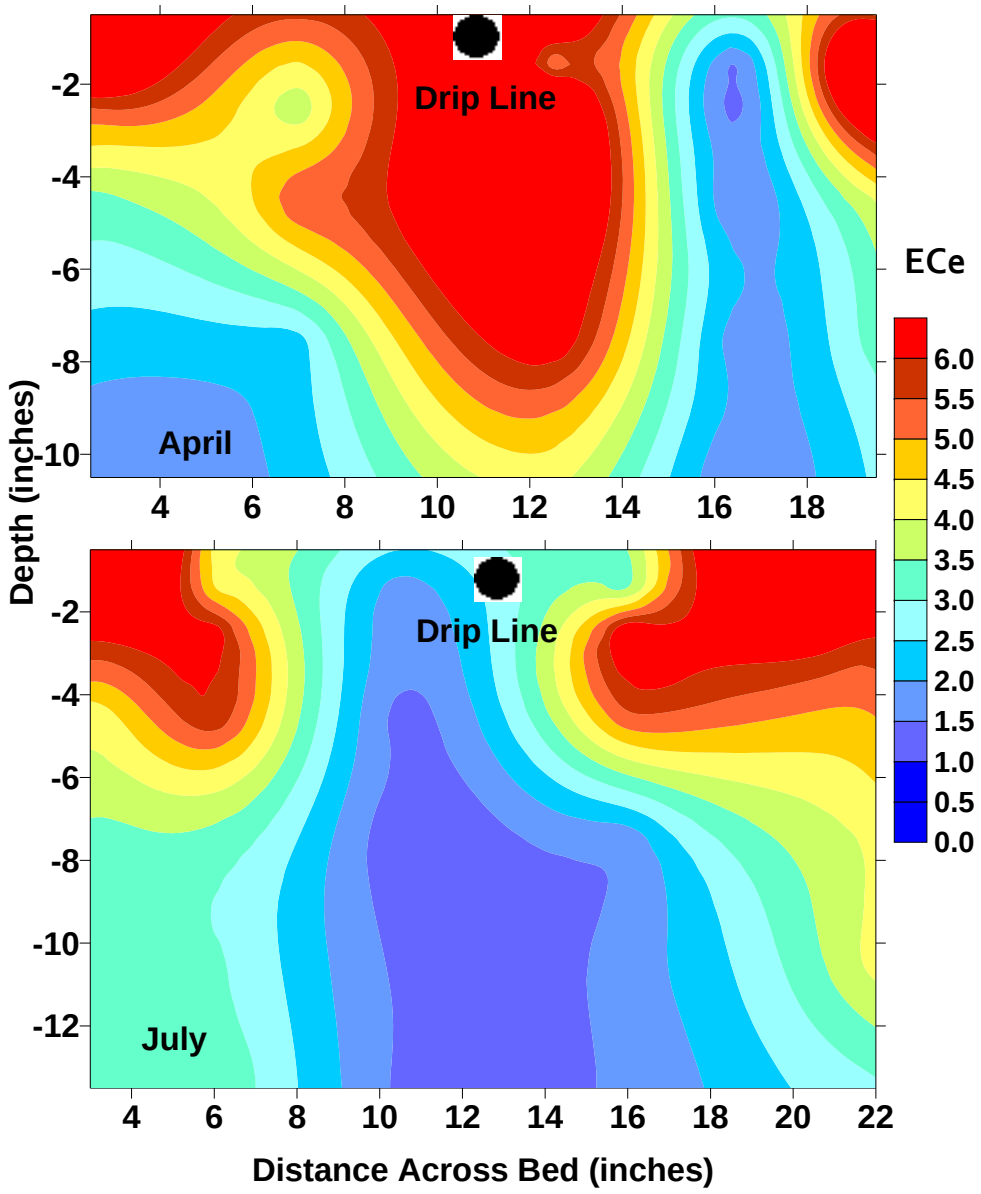

No pre-plant irrigation
Depth interval (feet)
0-1
1-2
2-3
3-4
ECe (dS/m)
0
2
4
6
8
10
12
14
16
Spring 82
Fall 82
Spring 83
Fall 83

Controlling soil salinity under drip irrigation

- Highly concentrated leaching near drip lines due to localized wetting patterns
- Pre-plant irrigation (sprinkle irrigation) – may be required for subsurface drip irrigation
- Effect of drip line placement on root distribution and soil salinity
  - Drip line and plant row locations coincide – concentrated leaching in the root zone
  - Drip line and plant row locations offset – may have salinity control problems

Surface drip irrigation; saline irrigation water; no shallow ground water

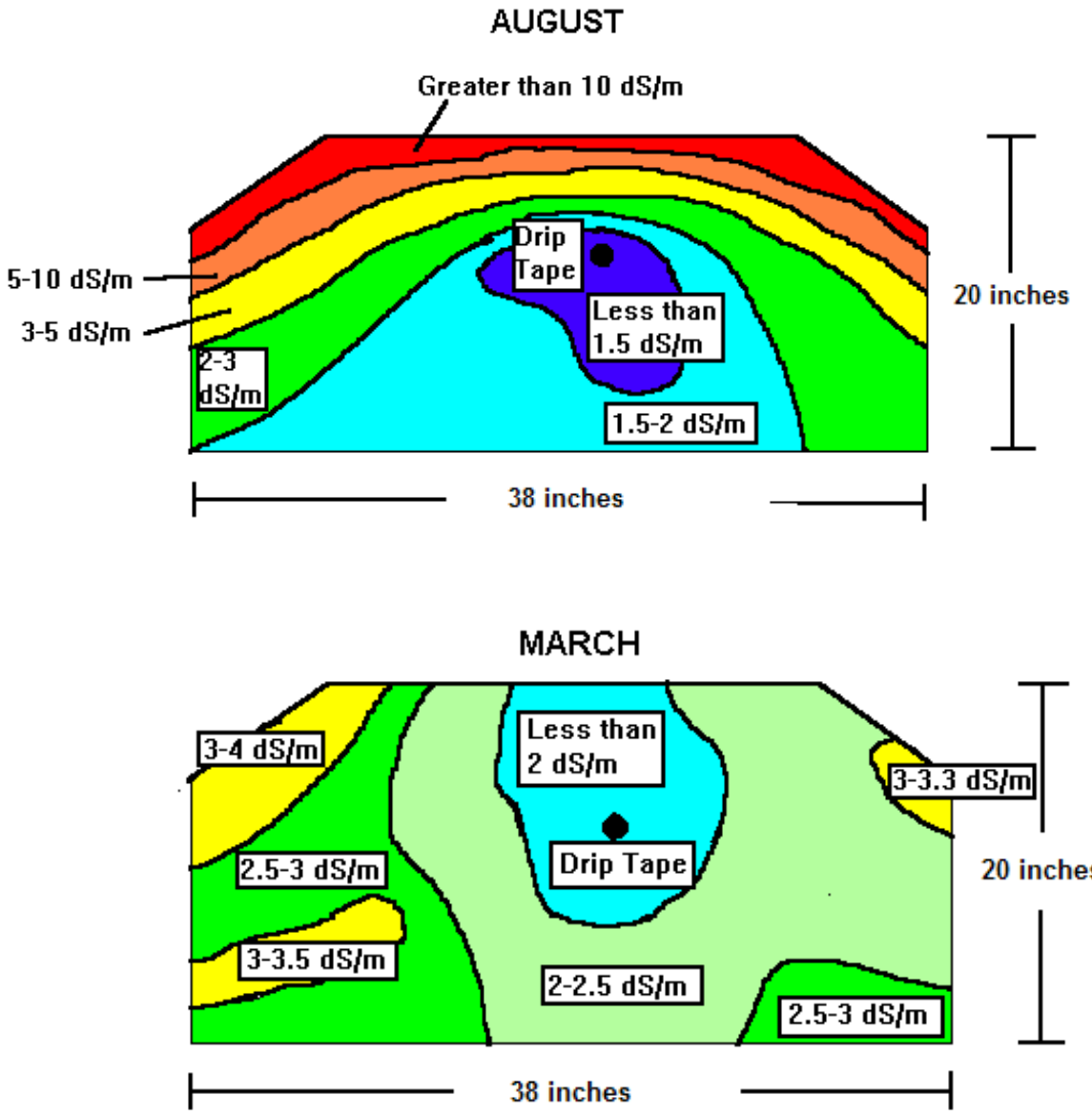
Soil Salinity (ECe in dS/m)

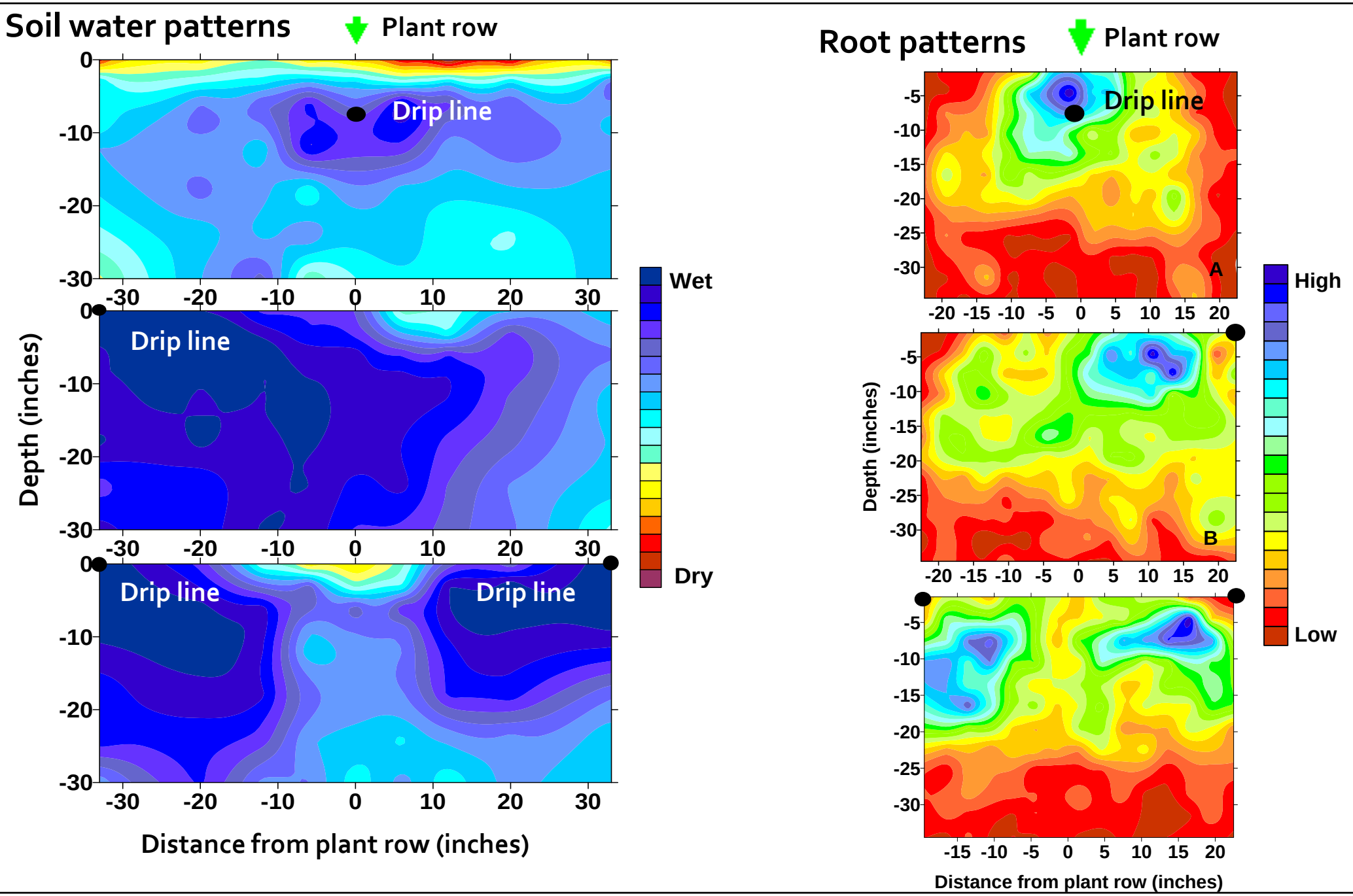


No leaching under drip irrigation

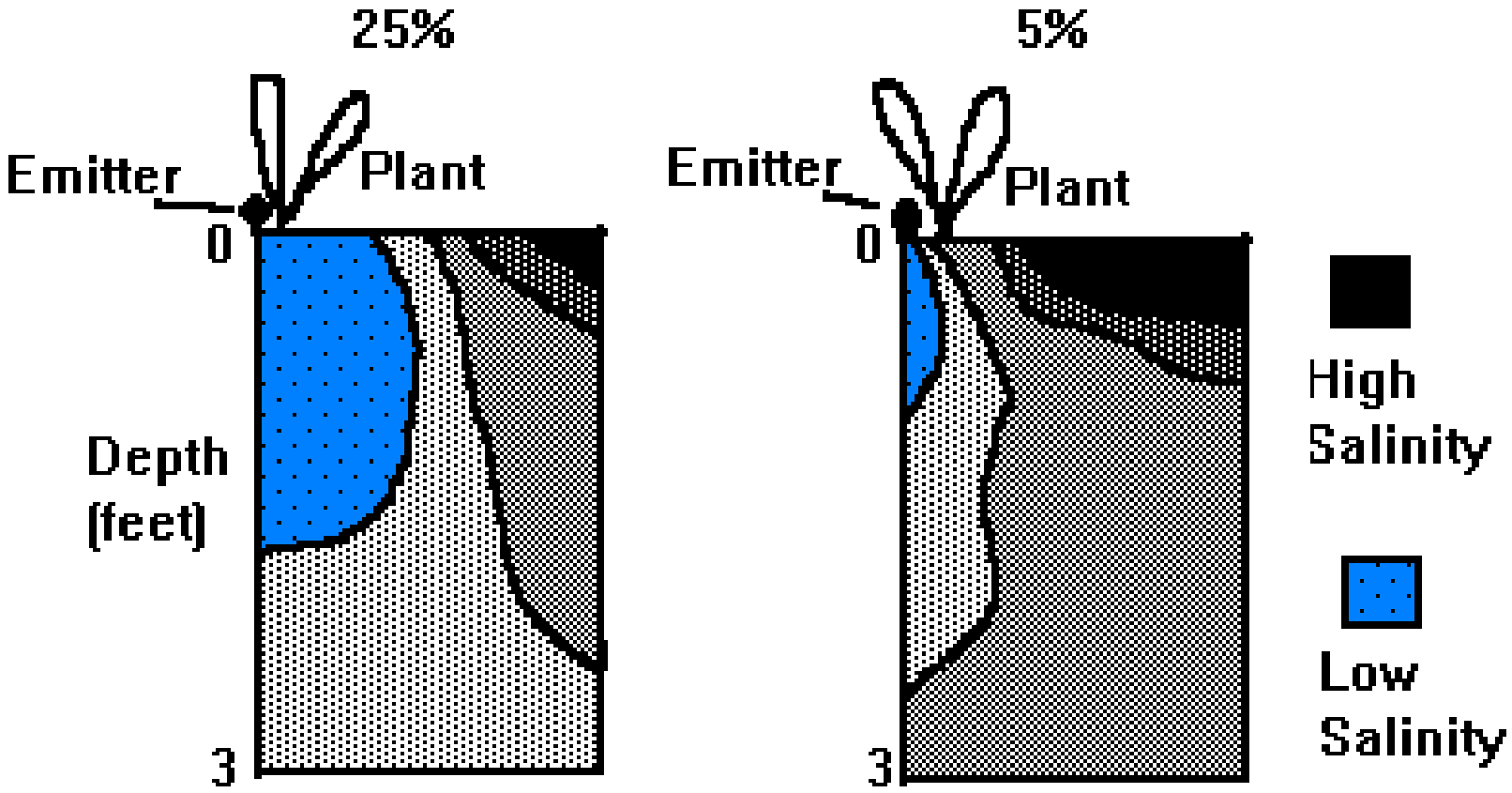
Leaching under drip irrigation

Pre-plant irrigation- subsurface drip irrigation



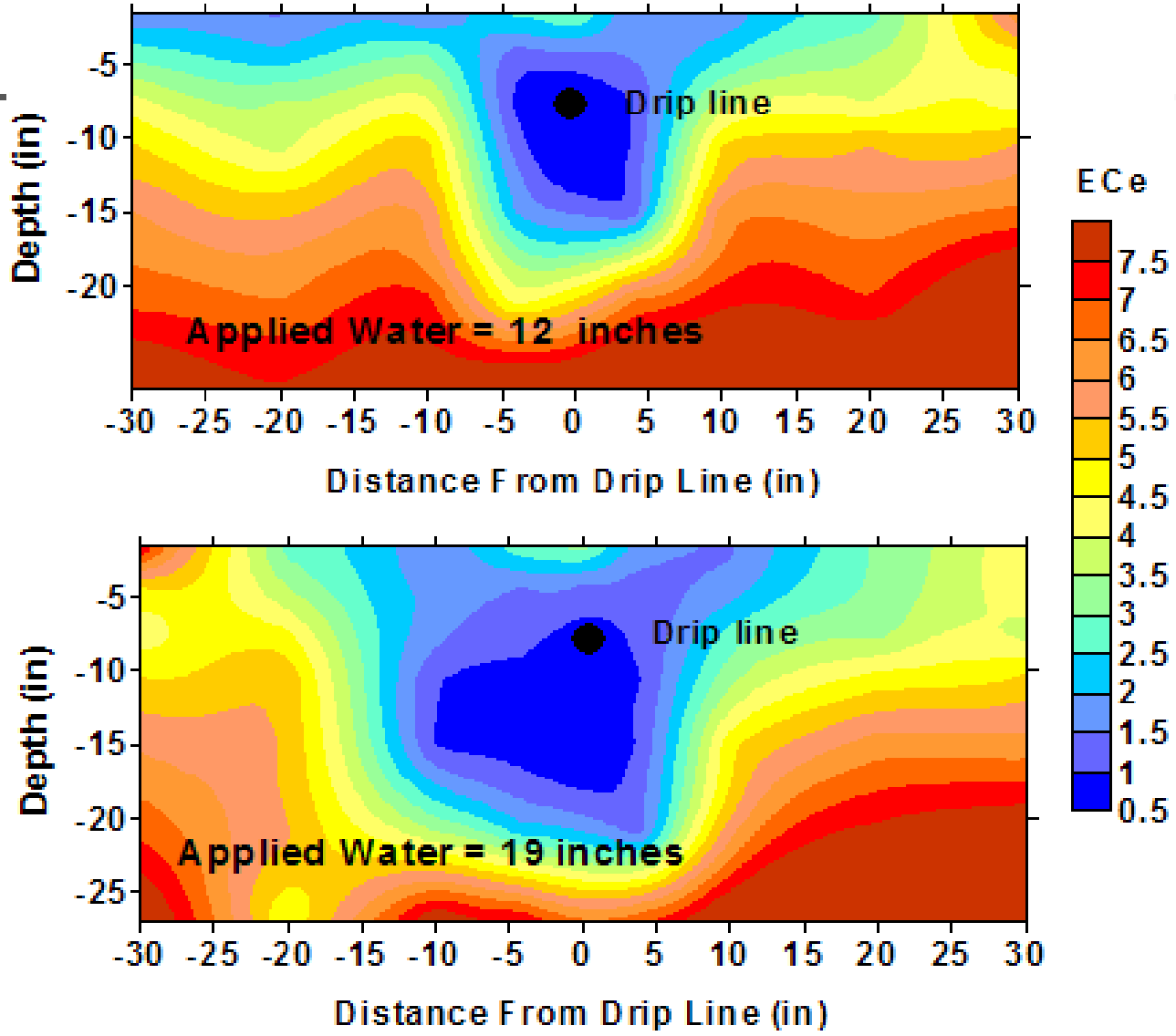

Soil water patterns
Plant row
Drip line
Drip line
Drip line
Drip line
Wet
Dry
Depth (inches)
Distance from plant row (inches)
Root patterns
Plant row
Drip line
A
B
High
Low
Depth (inches)
Distance from plant row (inches)

Effect of amount of applied water of volume of low salt soil under surface drip irrigation

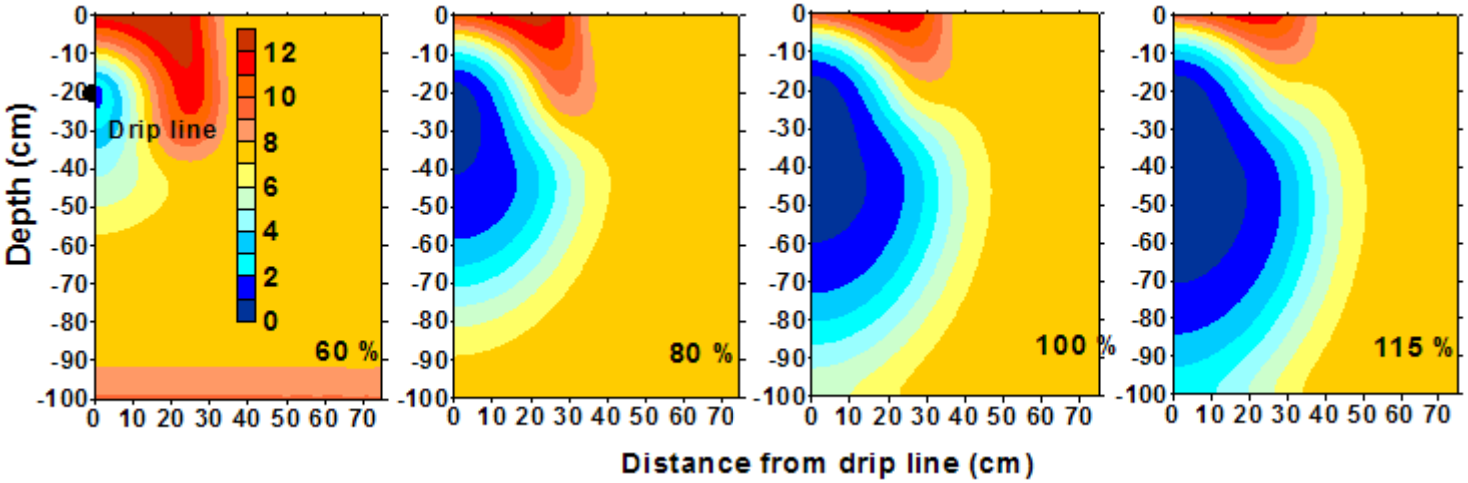


Note: as the leaching fraction increases, the amount of relatively low-salt soil increases.

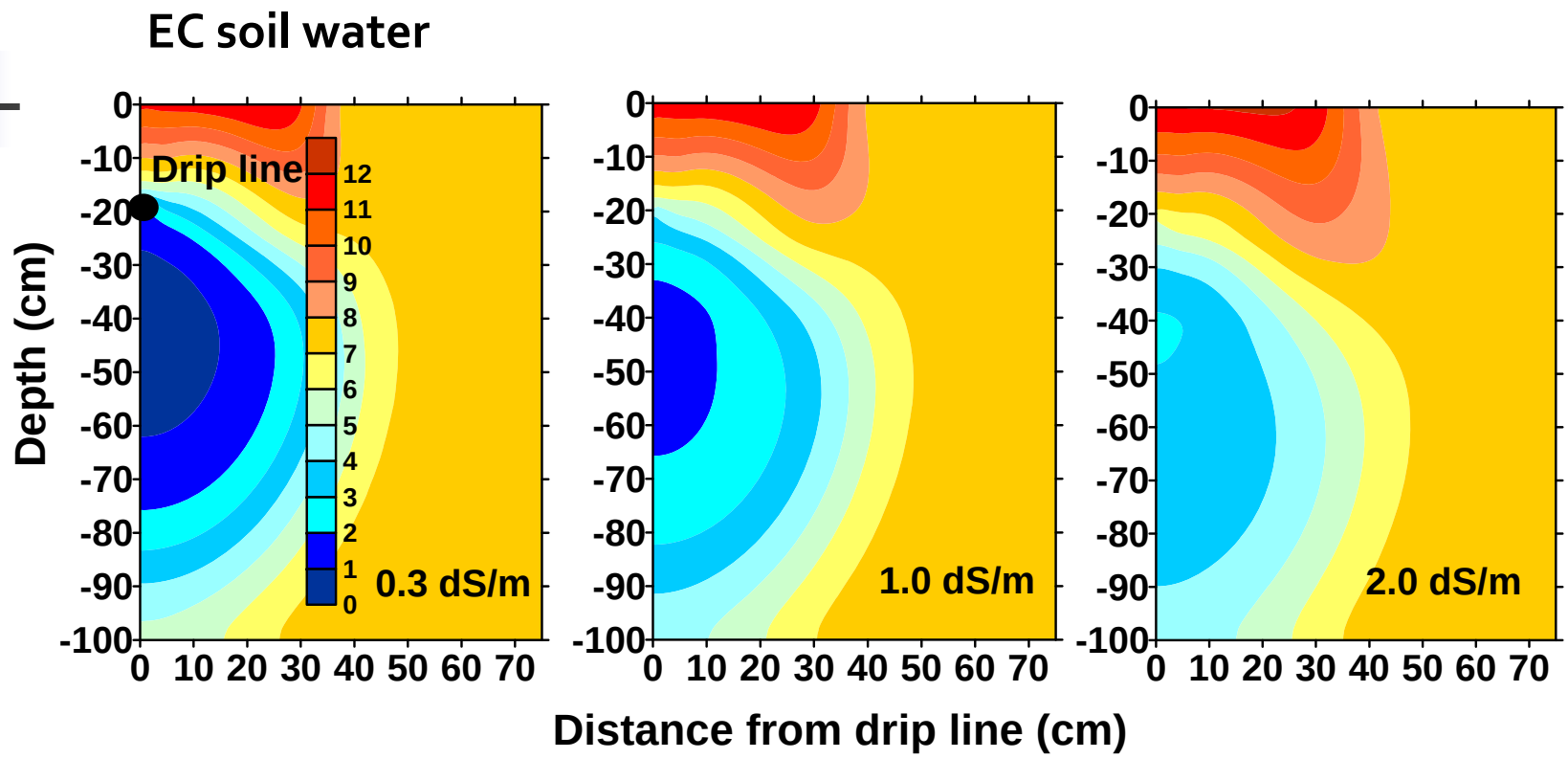
Effect of amount of applied water of volume of low salt soil under subsurface drip irrigation



Effect of amount of applied water of volume of low salt soil under surface drip irrigation – computer simulation study



Effect of irrigation water salinity



Recommended salinity control practices for subsurface drip irrigation of processing tomatoes under saline, shallow groundwater conditions

- Sufficient localized leaching must occur near drip lines to maintain profitable yields
- Seasonal water applications should be about equal to the seasonal evapotranspiration (ET) to provide sufficient localized leaching and to reduce water table response to irrigation
- Use relatively low salt irrigation water (ECi equal to or less than about 1 dS/m)
- Irrigation frequency – daily to 2 to 3 times per week.
- Periodic leaching of salt accumulated above buried drip lines may be necessary with sprinklers for stand establishment
- Drip system should be designed for high uniformity (DU>90% along drip line)
- Periodic system maintenance must be performed to prevent clogging of drip lines, which will reduce the localized leaching

Estimating leaching fractions

- No entirely satisfactory method exists
- Assumptions used in some methods may not fit field situations

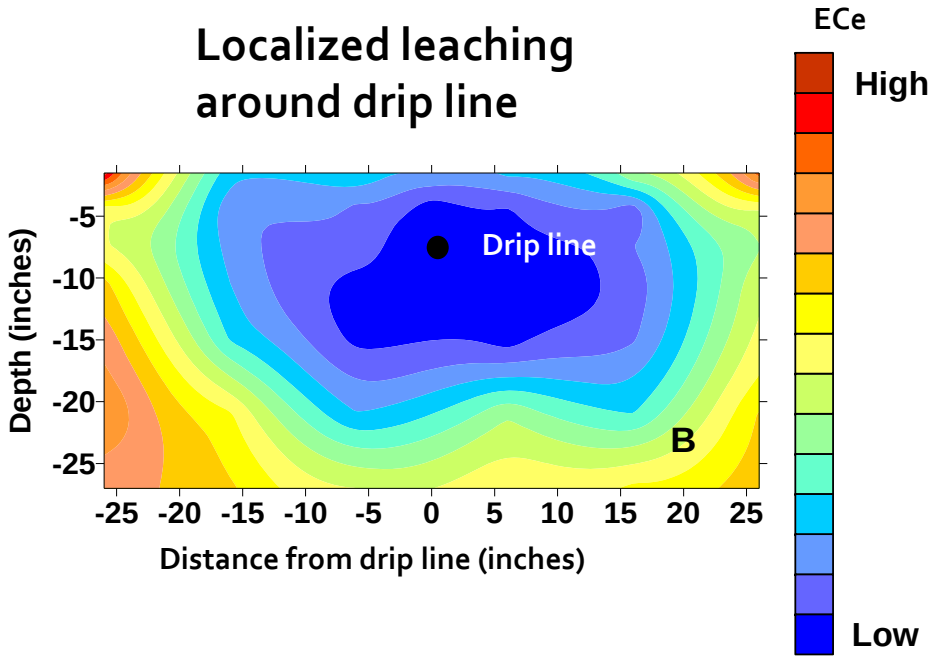
Water balance approach

- Measurements
  - Amount of applied water (AW)
  - Crop evapotranspiration (ET) – CIMIS, other
- Leaching fraction = 100 x (AW – ET) ÷ AW
- Field-wide average leaching fraction
- Seasonal or irrigation leaching fraction
- Some parts of the field may receive more leaching while others may receive less due to non-uniformity of applied water
- Appropriate for sprinkle, flood, and furrow irrigation
- May underestimate leaching fractions for drip irrigation

Water balance leaching fraction under drip irrigation

Year	Leaching Fraction (%)
	DI
1999	0
2000	22
2001	0
	BR1
1999	0
2000	0
2001	1
	DE
2000	17
2001	9
	BR2
2002	0

Localized leaching around drip line



Computer simulations (HYDRUS-2D): water balance leaching fraction and actual leaching fraction for drip irrigation

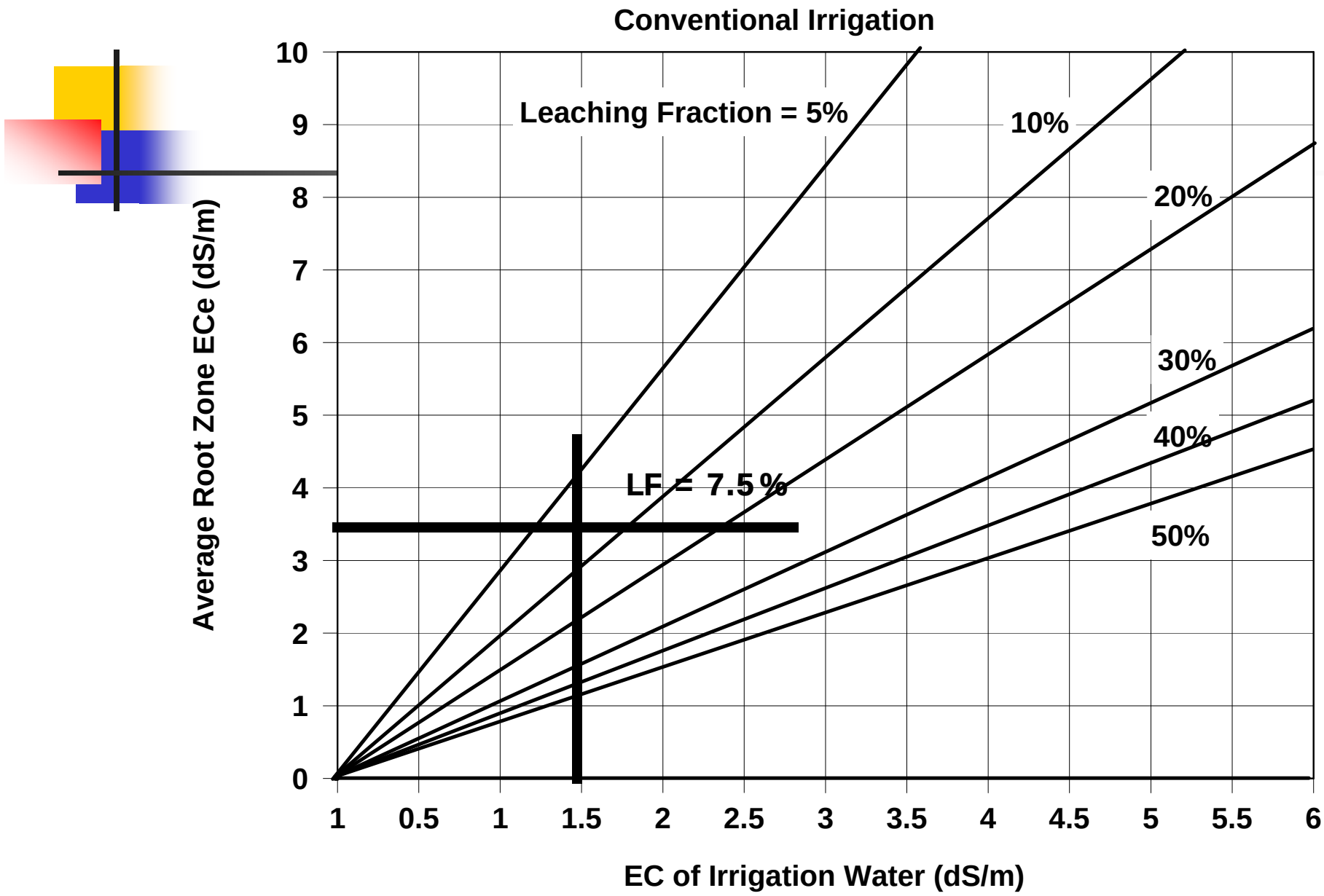
Applied water (% of potential ET)	Water balance leaching fraction (%)	Actual Leaching fraction (%)
60	0	7.7
80	0	17.3
100	0	24.5
115	15	30.9

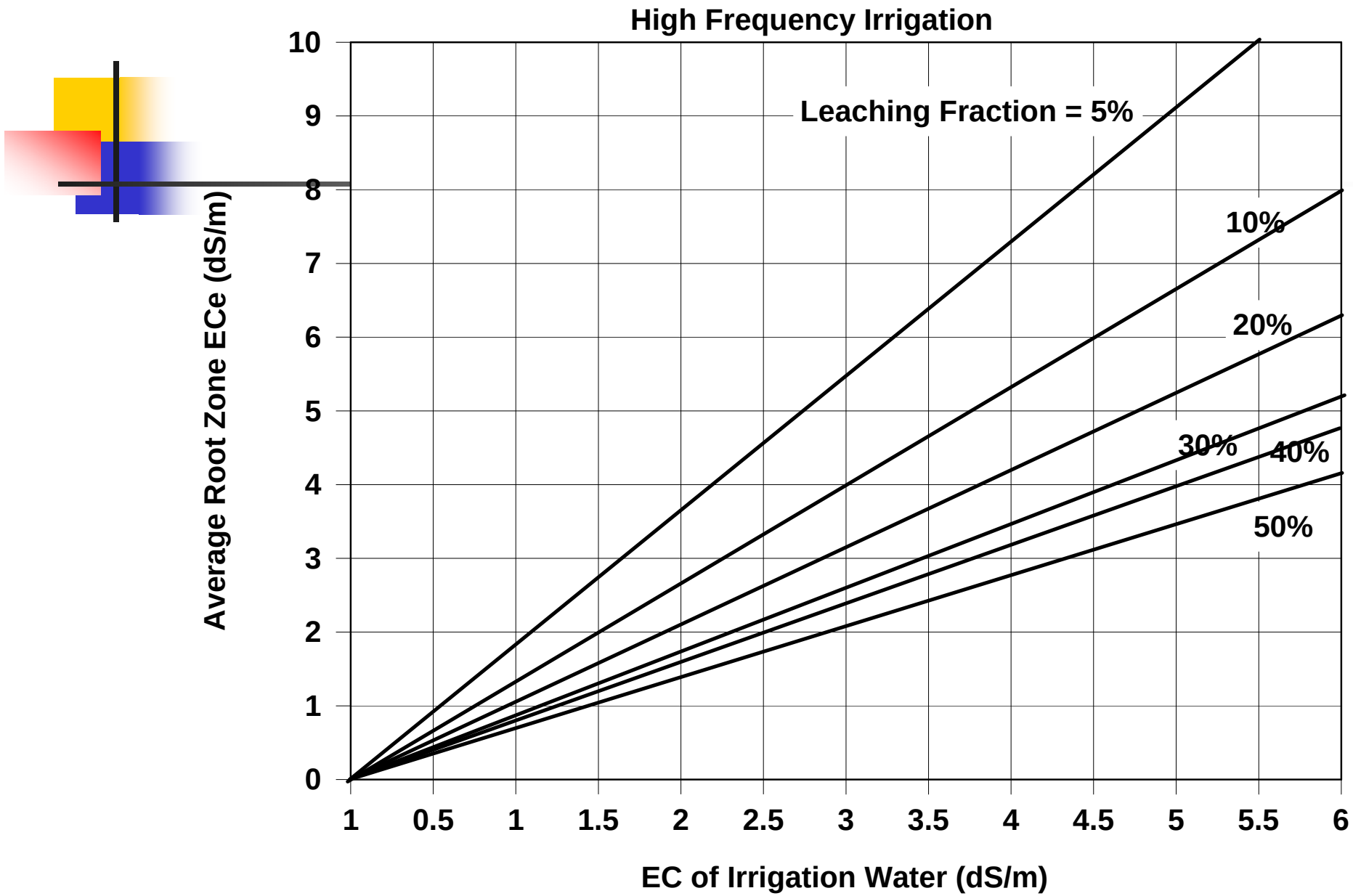
Notes:

- Applying an amount of water equal to the ET does not result in an irrigation efficiency = 100% for drip irrigation, as is commonly assumed
- High irrigation efficiency under drip irrigation occurs only for severe deficit irrigation conditions
- This behavior is due to the wetting pattern around drip lines and can not be avoided

Estimate leaching fraction from soil salinity data

- Measure root zone soil salinity (Ece)
- Measure irrigation water EC
- Use leaching charts to determine leaching fraction
- Assumptions
  - Root distribution
  - Steady-state leaching


Conventional Irrigation
Leaching Fraction = 5%
10%
20%
30%
40%
50%
LF = 7.5%
Average Root Zone ECe (dS/m)
EC of Irrigation Water (dS/m)
0
1
2
3
4
5
6
7
8
9
10
1
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6


High Frequency Irrigation
Leaching Fraction = 5%
10%
20%
30%
40%
50%
Average Root Zone ECe (dS/m)
EC of Irrigation Water (dS/m)
0
1
2
3
4
5
6
7
8
9
10
1
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6

Is the calculated leaching fraction sufficient?

Measure soil salinity

- Sample soil in the root zone and measure the ECe
  - Individual samples – identify zones of high salinity
    - Cost considerations
    - Information on variability
  - Composite samples – sample in zones of high salinity
    - Lower cost
    - No information on variability
  - Sampling strategies
    - Systematic – sample on a grid
    - Random
- Compare root zone soil salinity with threshold values for a specific crop
- Monitor soil salinity over time

Monitor soil salinity over time

- Periodic sampling in the root zone with soil samples
- Continuous monitoring with soil moisture/salinity sensors
- Monitor in zones of high salinity at several locations within a field
- Concerns
  - Sufficient samples to reduce effect of soil variability
  - Little or no variability over time in laboratory processing of samples

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