Strategies to minimize crop loss under saline conditions

Steve Grattan, Ph.D

Department of Land, Air and Water Resources

University of California, Davis

Salinity

- Salts are found in all irrigation waters
- Salts can accumulate in root zone and damage crops
- Salinity is a condition when the salt concentration in the root zone is in excess for optimal growth or quality

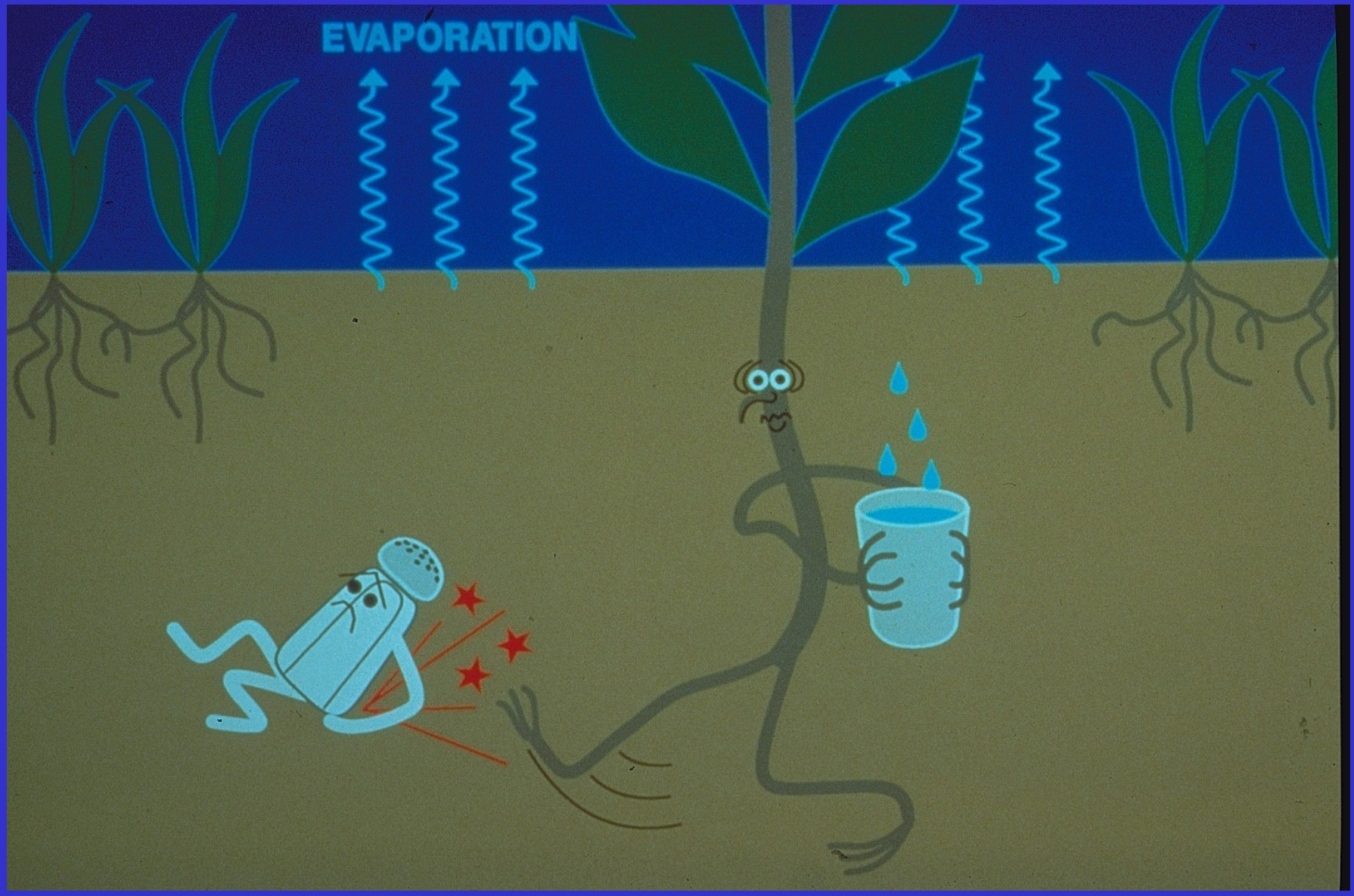
Salinity

How does salinity affect crops?

Salt affects crop growth and performance several ways

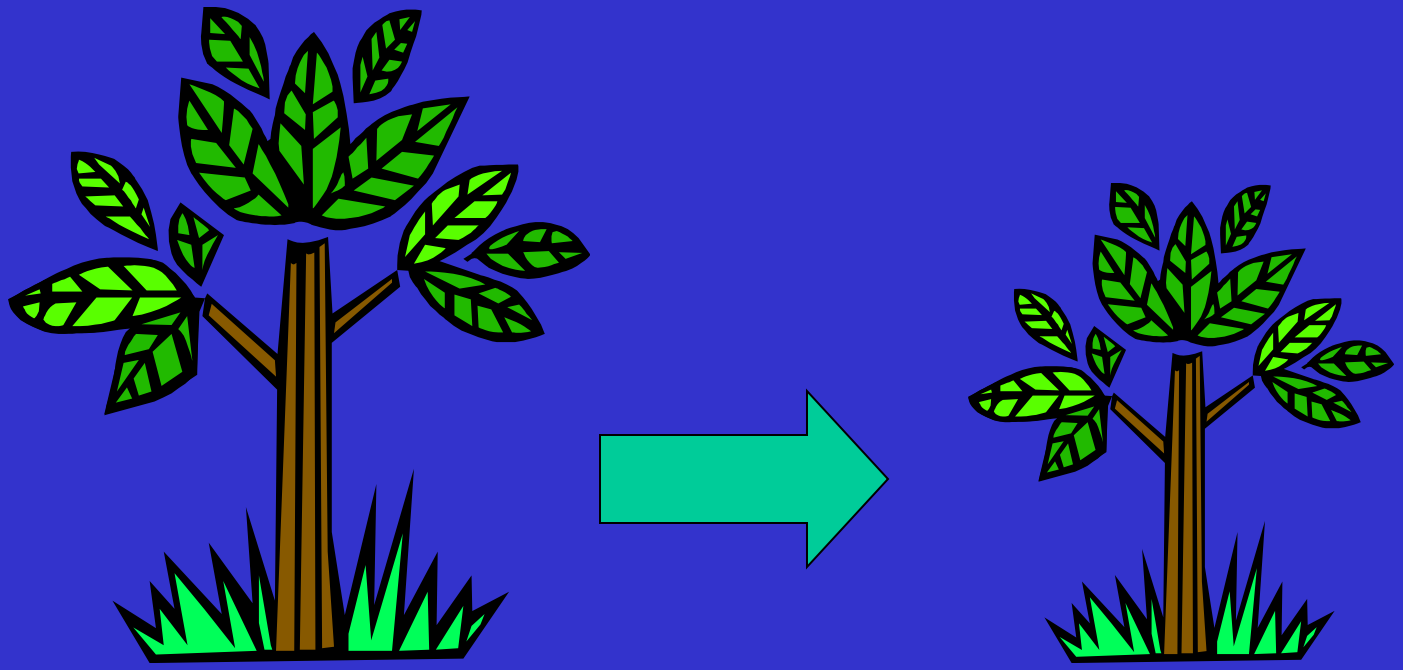
- Osmotic effects
- Ion toxicities
- Nutritional disorders

} Specific ion effects



Glycophytes (most crop plants)

The overall osmotic effect is stunting of crop growth



Non-stressed crop

Salt-stressed crop

Note: moderately salt-stressed crops may appear healthier than non stressed plants

Osmotic effects

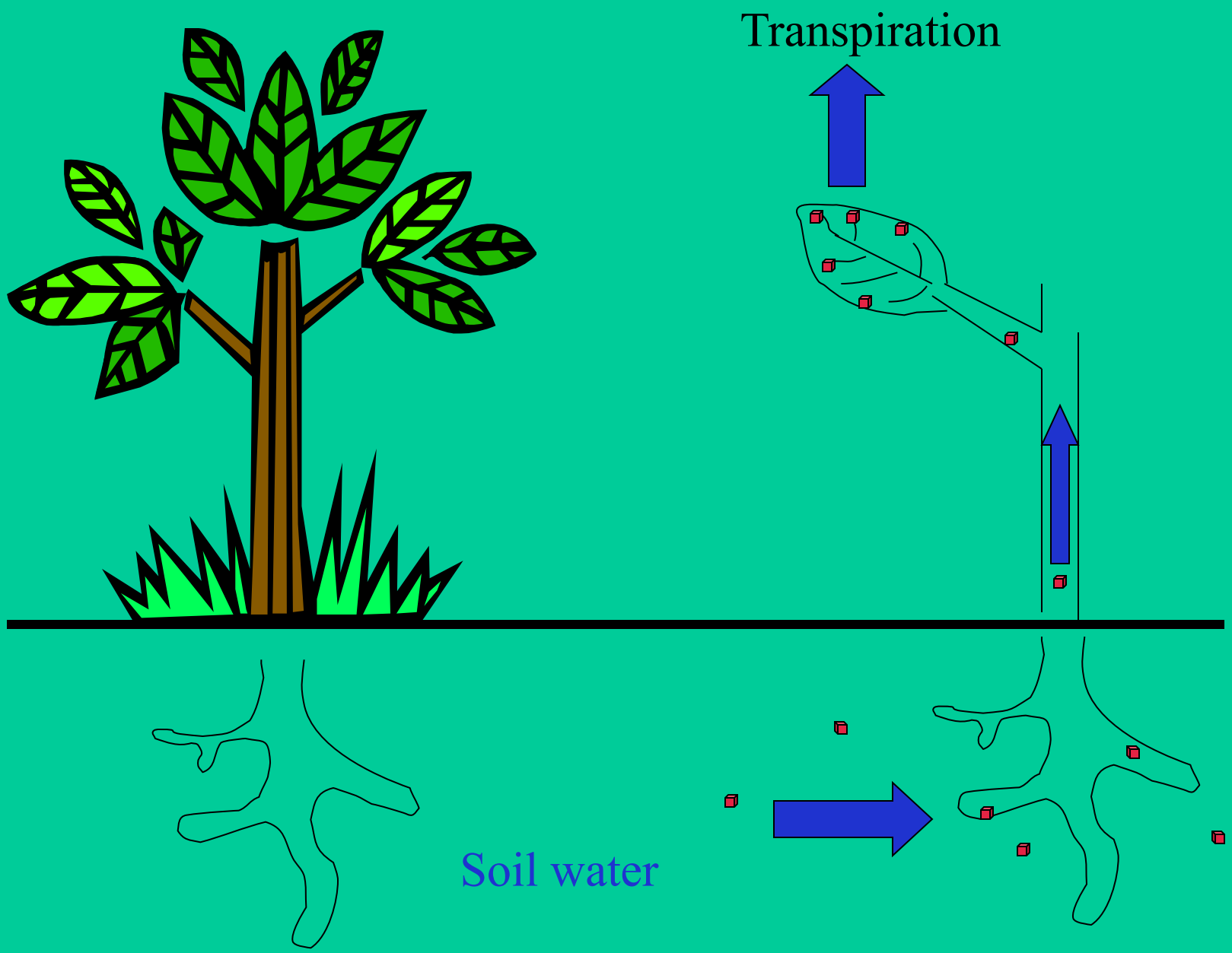
Increasing salinity (EC, dS/m)

Specific ion toxicity

(Chloride, boron and sodium)

Many trees, vines and strawberries

Cl Accumulation



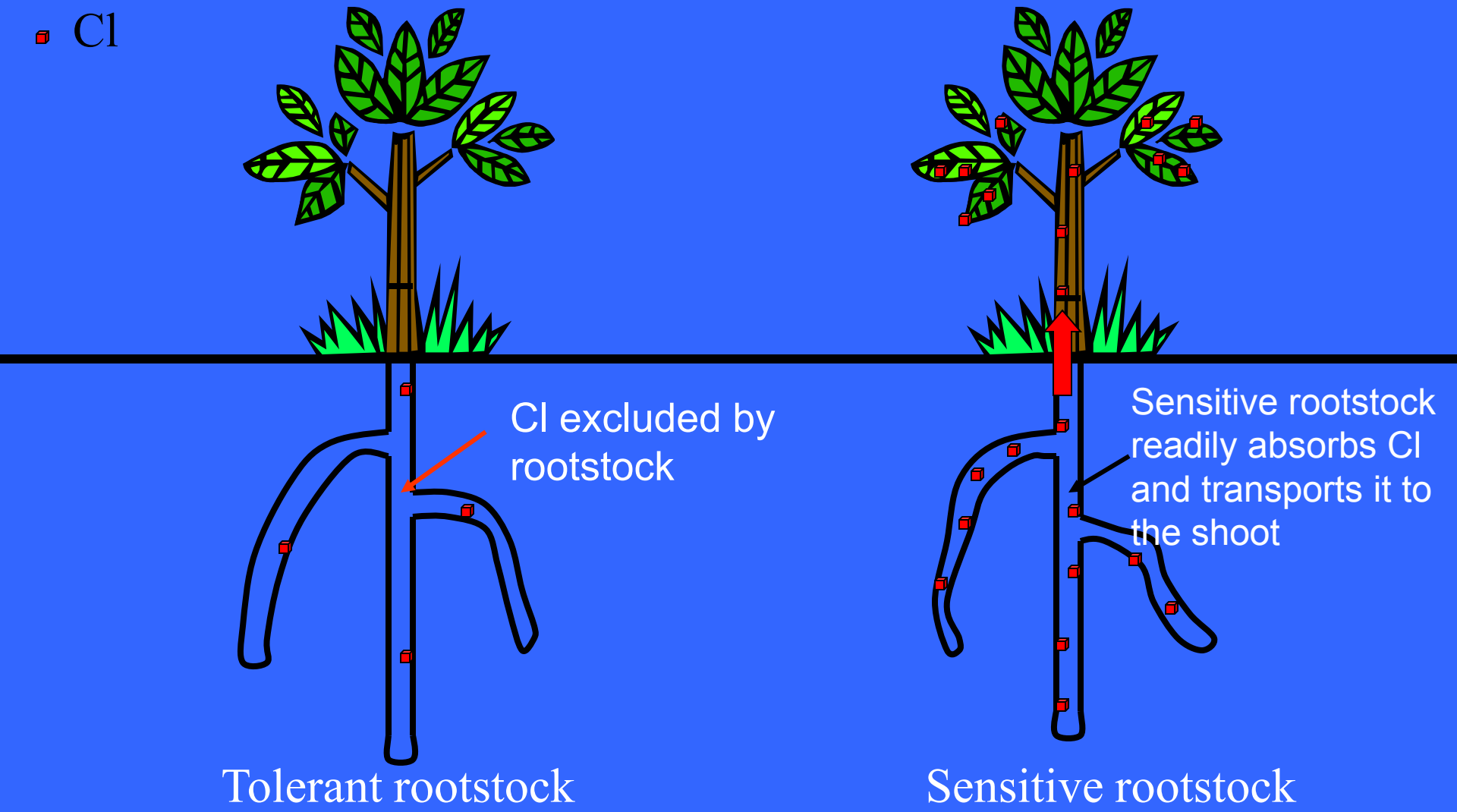
Boron and Chloride accumulation patterns in citrus

- B

Cl

Tolerance to ion toxicity is controlled by the rootstock

- Cl



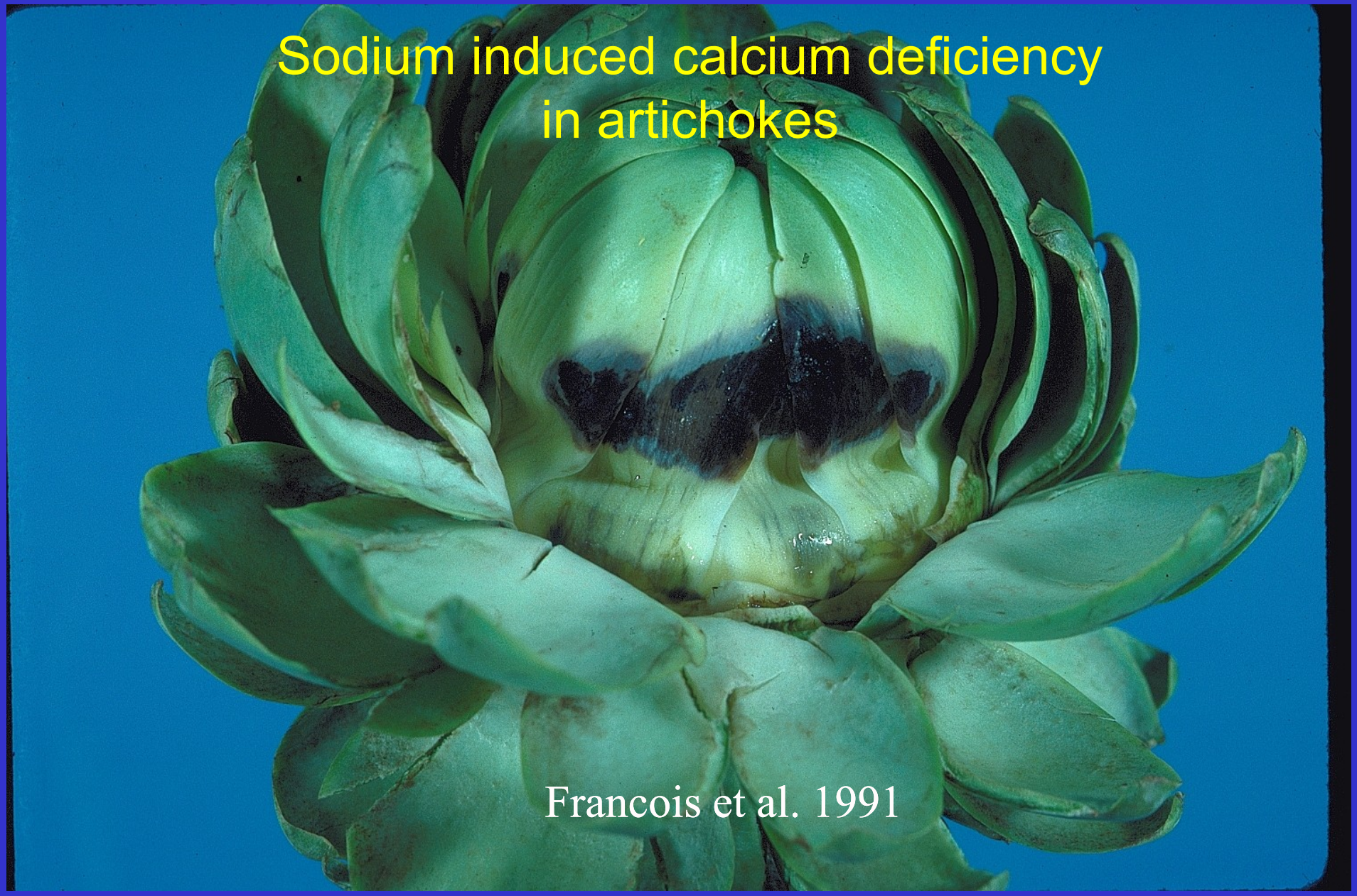
Salinity induced nutritional deficiencies

Na induced Ca deficiency
Salt induced P deficiency
Na induced K deficiency

Blossom End Rot

From Miller et al., Ohio State University

Sodium induced calcium deficiency in artichokes



Francois et al. 1991

Ca composition of bracts from salinized Artichoke buds*

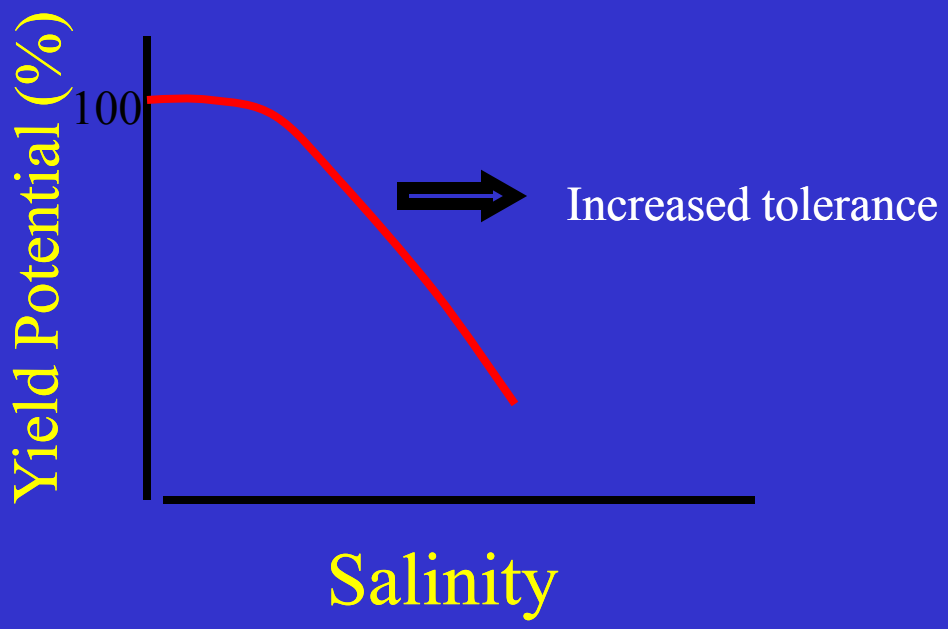
ECe (dS/m)	Ca in Inner bracts (mmol/kg dw)	Ca in Outer bracts (mmol/kg dw.)
4.6	25	101
6.6	35	105
7.4	17	100
8.7	14	131
10.6	14	120
11.6	14	143

* Grown in hot desert climate with NaCl +$CaCl_2$

Francois et al. 1991

Salt Tolerance

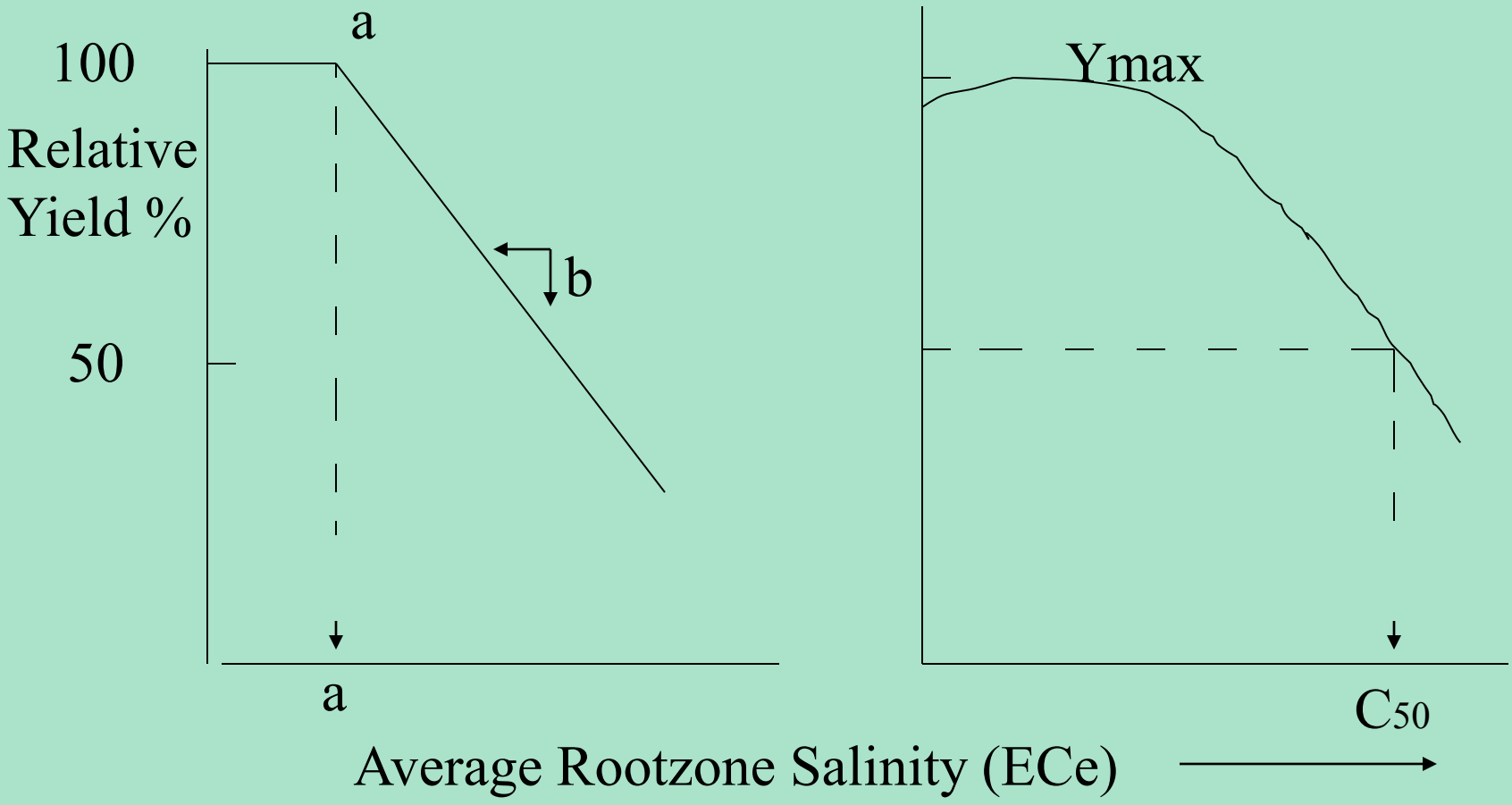
- Survival (ecology)
- Appearance (ornamental horticulture)
- Yield (horticulture and agronomy)



Characterizing Salinity-Yield Relations

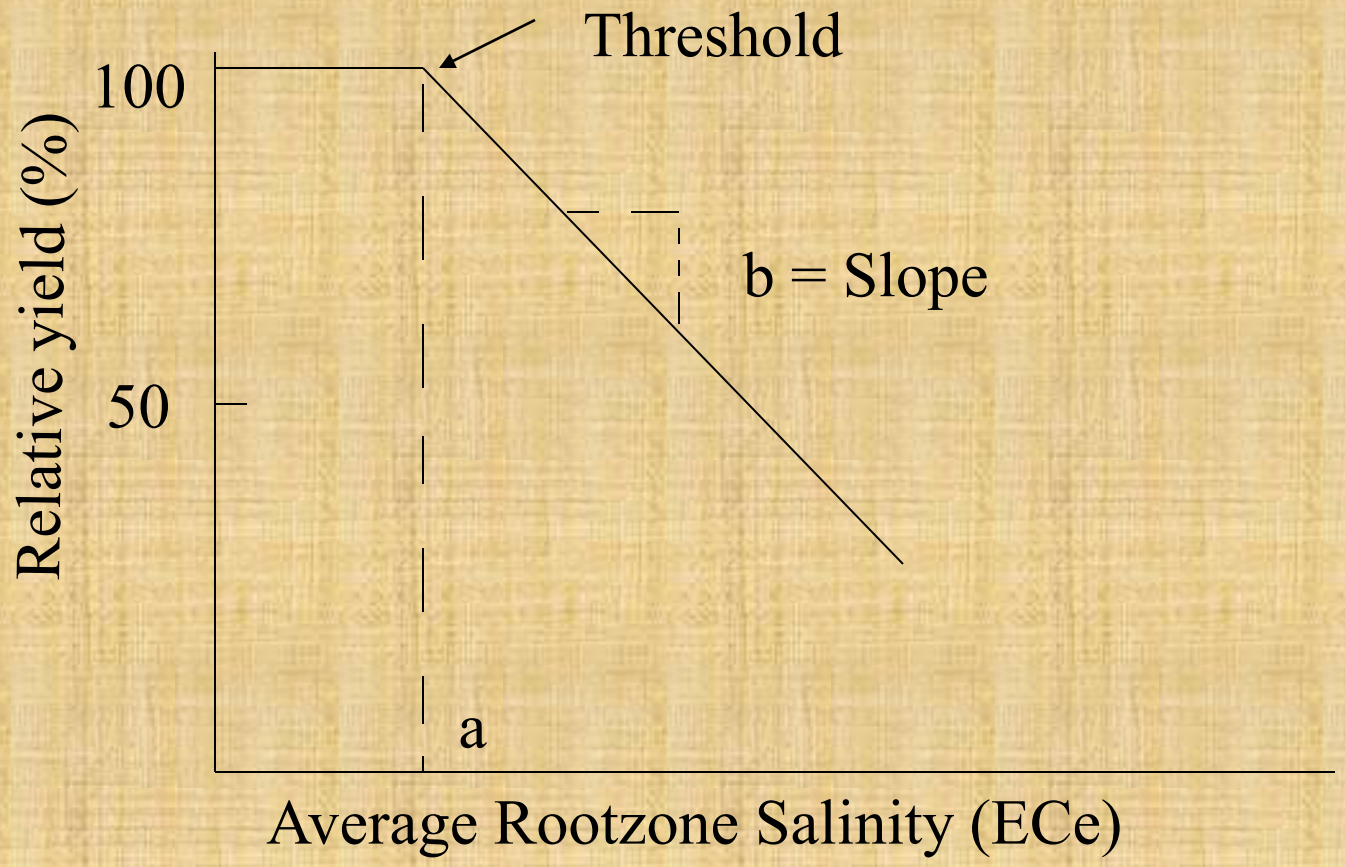
Maas and Hoffman, 1977

van Genuchten and Hoffman, 1984



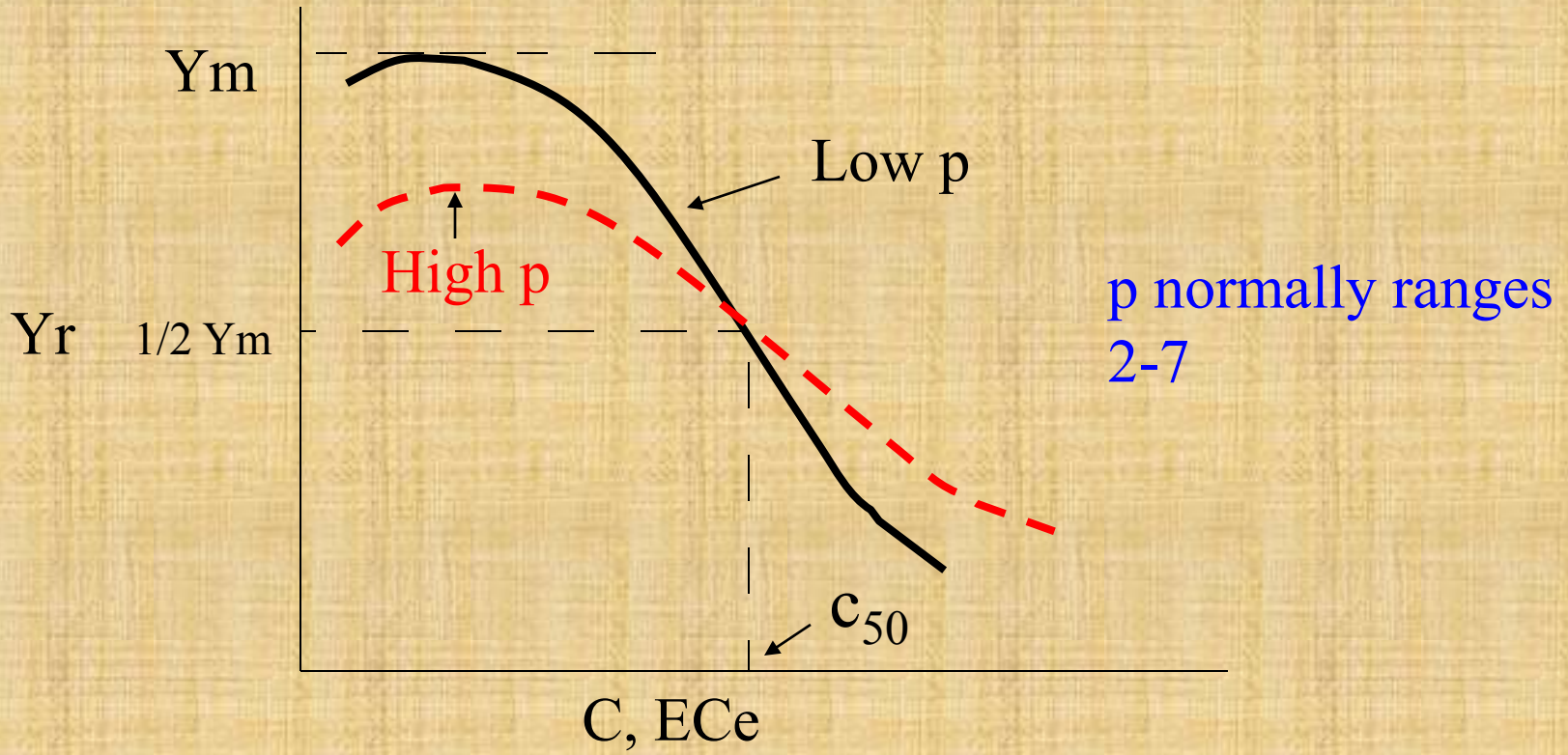
Maas and Hoffman (1977)

- Relates Relative Yield to ECe
- Steady-state conditions (ie salinity and water content static)
- Piece wise linear fit
- Yield (%) = 100 - b (ECe - a)

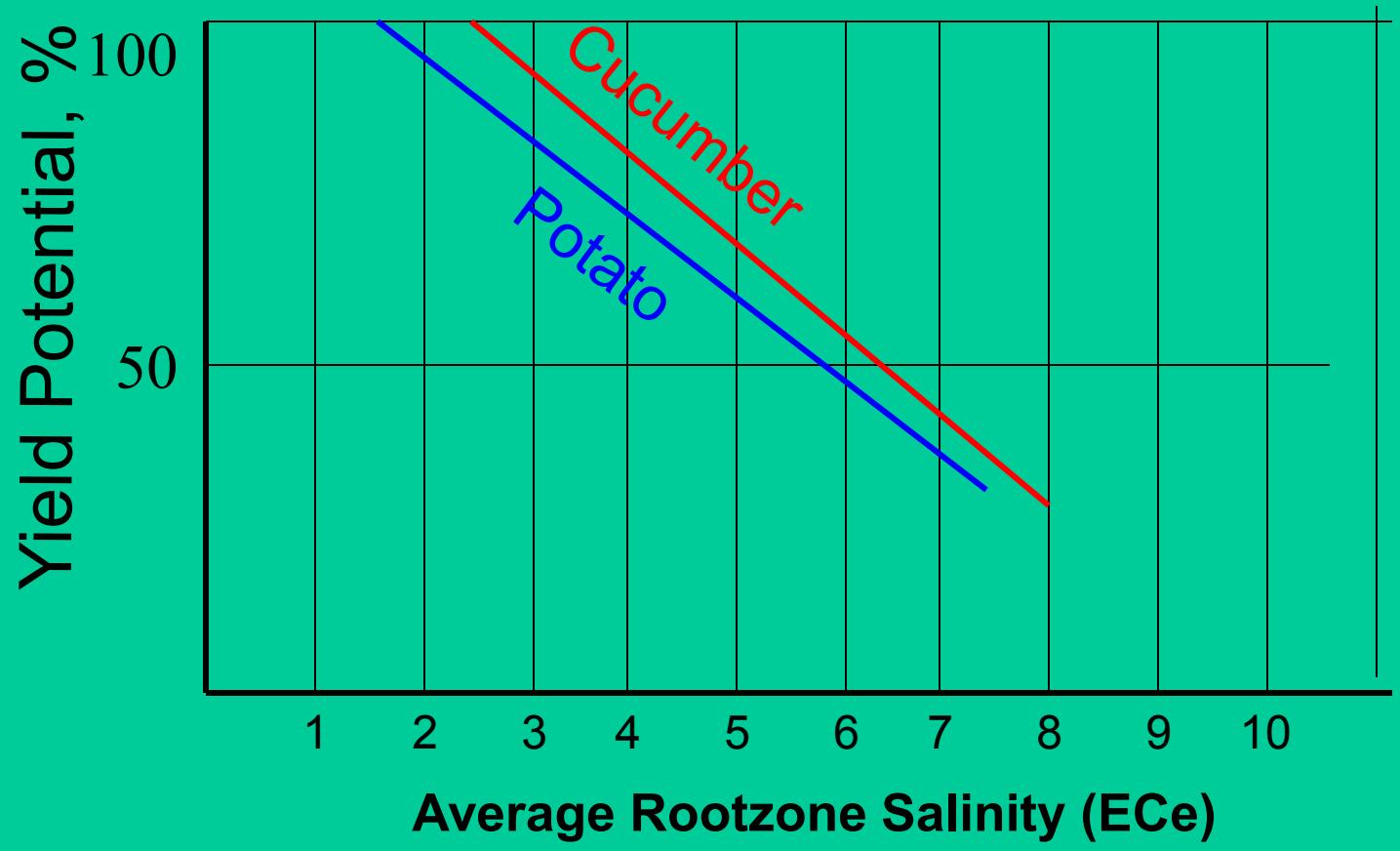


van Genuchten and Hoffman (1984)

- Relates yield to average root zone salinity
- Steady state conditions
- Non-linear function
- $Yr = Ym/[1 + (c/c_{50})^p]$

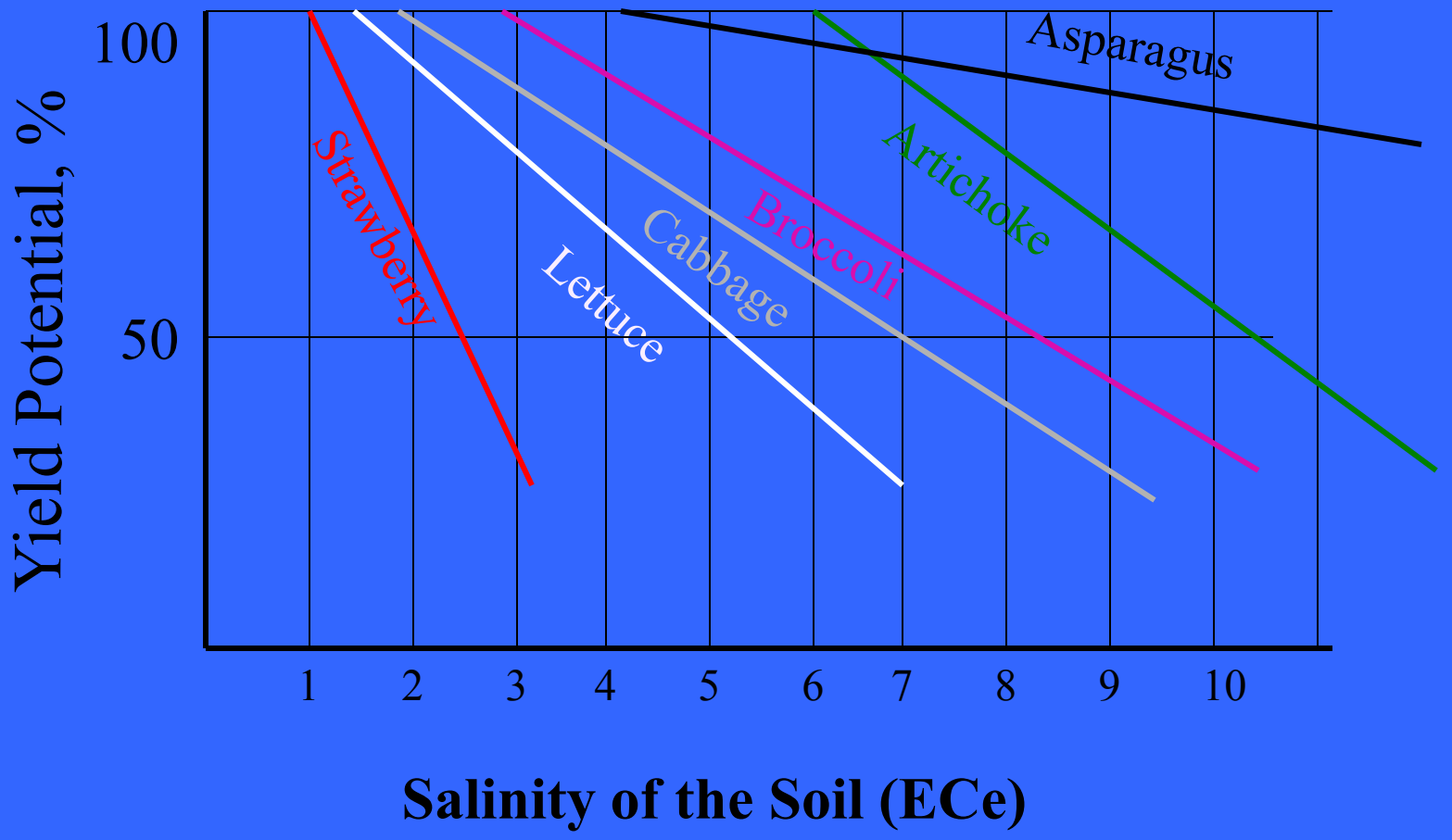


Crop salt tolerance



Salinity coefficients from Maas and Grattan 1999 "Crop yields as affected by salinity" ASA Monograph 38.

Salt tolerance of Strawberries and Vegetables



How can we use these salt tolerance Relationships to minimize salt stress?

Salt tolerance is based on soil salinity (ECe)

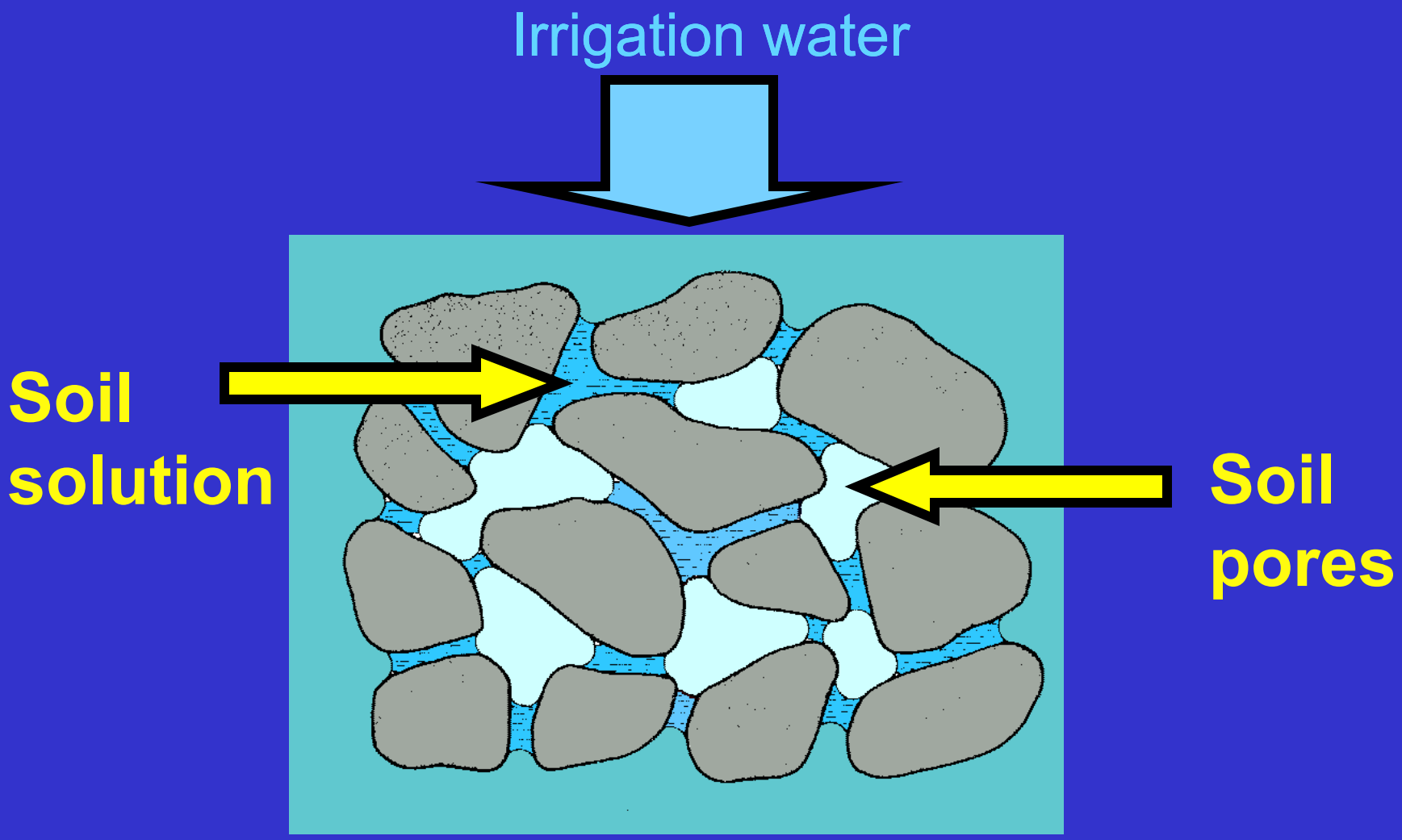
How does this help with my irrigation water quality report that gives me ECw?

What is the relationship between ECw and ECe?

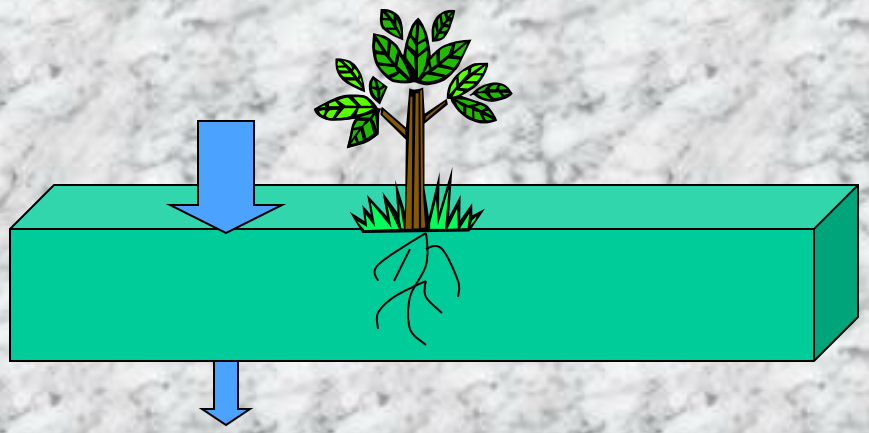
- ECw = electrical conductivity of the irrigation water

- ECe = electrical conductivity of the saturated soil paste

Irrigation water interacts with the soil



Leaching Fraction (LF)

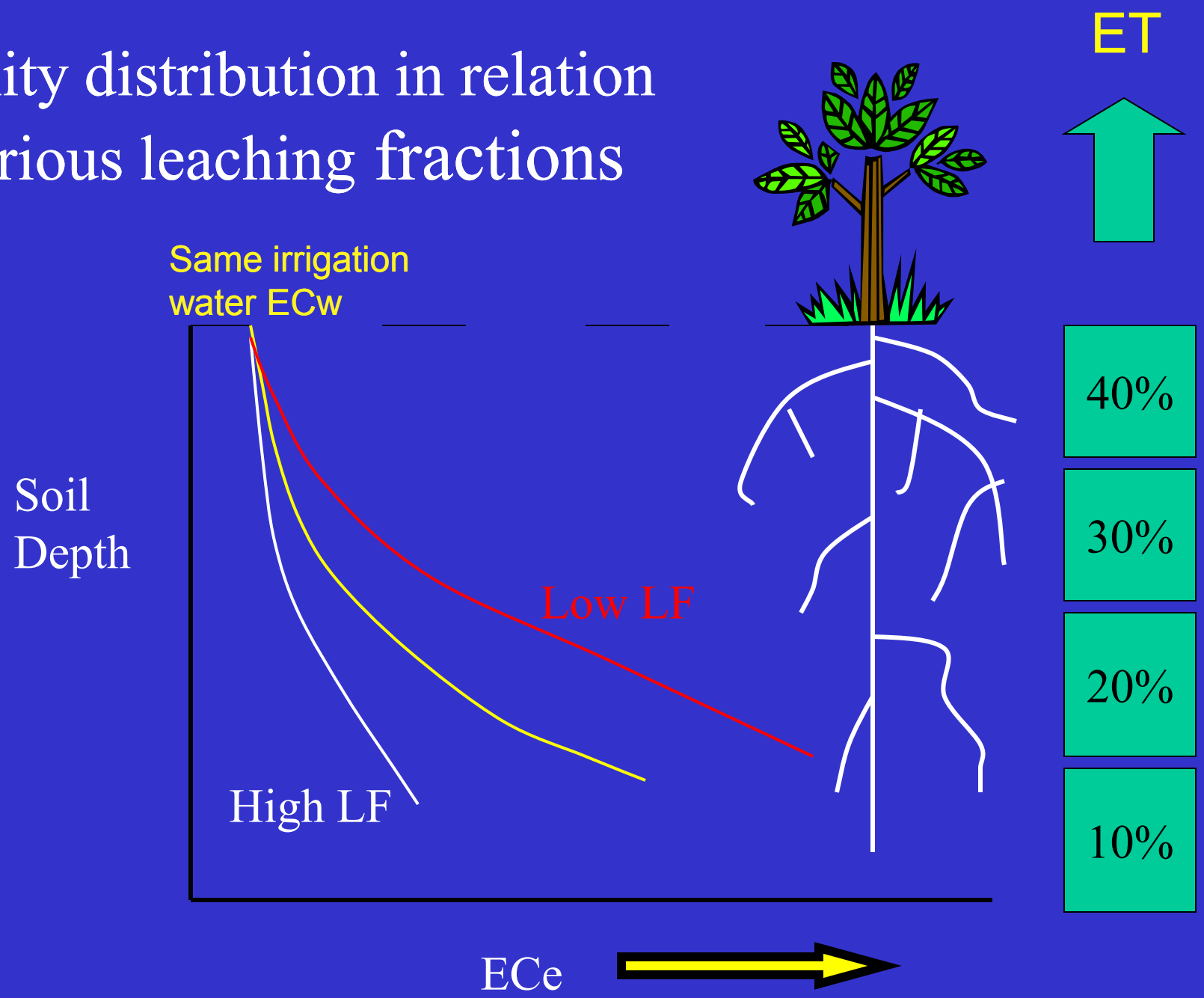


LF = volume of drainage water / volume of infiltrated water

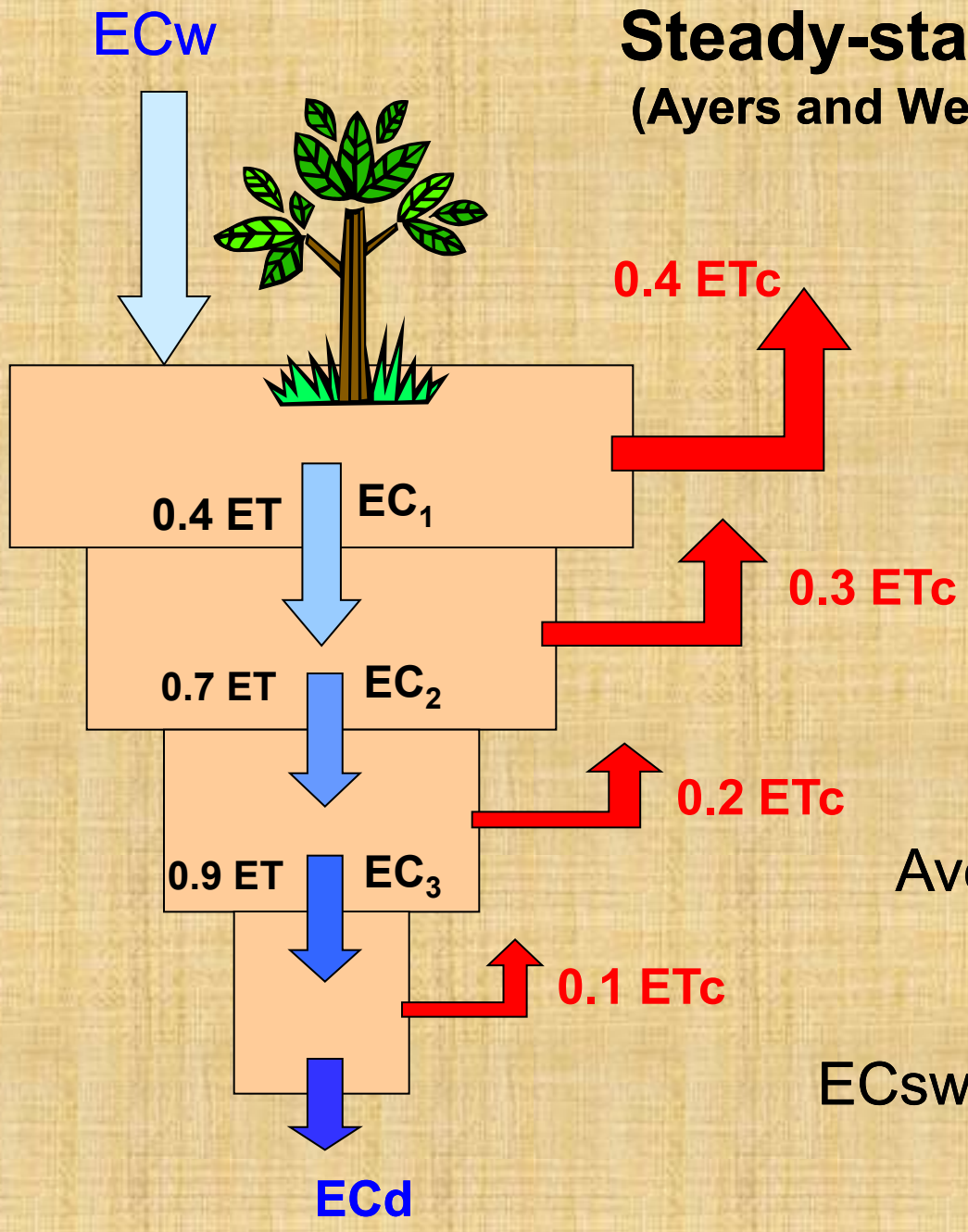
LF = depth of drainage water / depth of infiltrated

LF = ECw / ECdw

Salinity distribution in relation to various leaching fractions



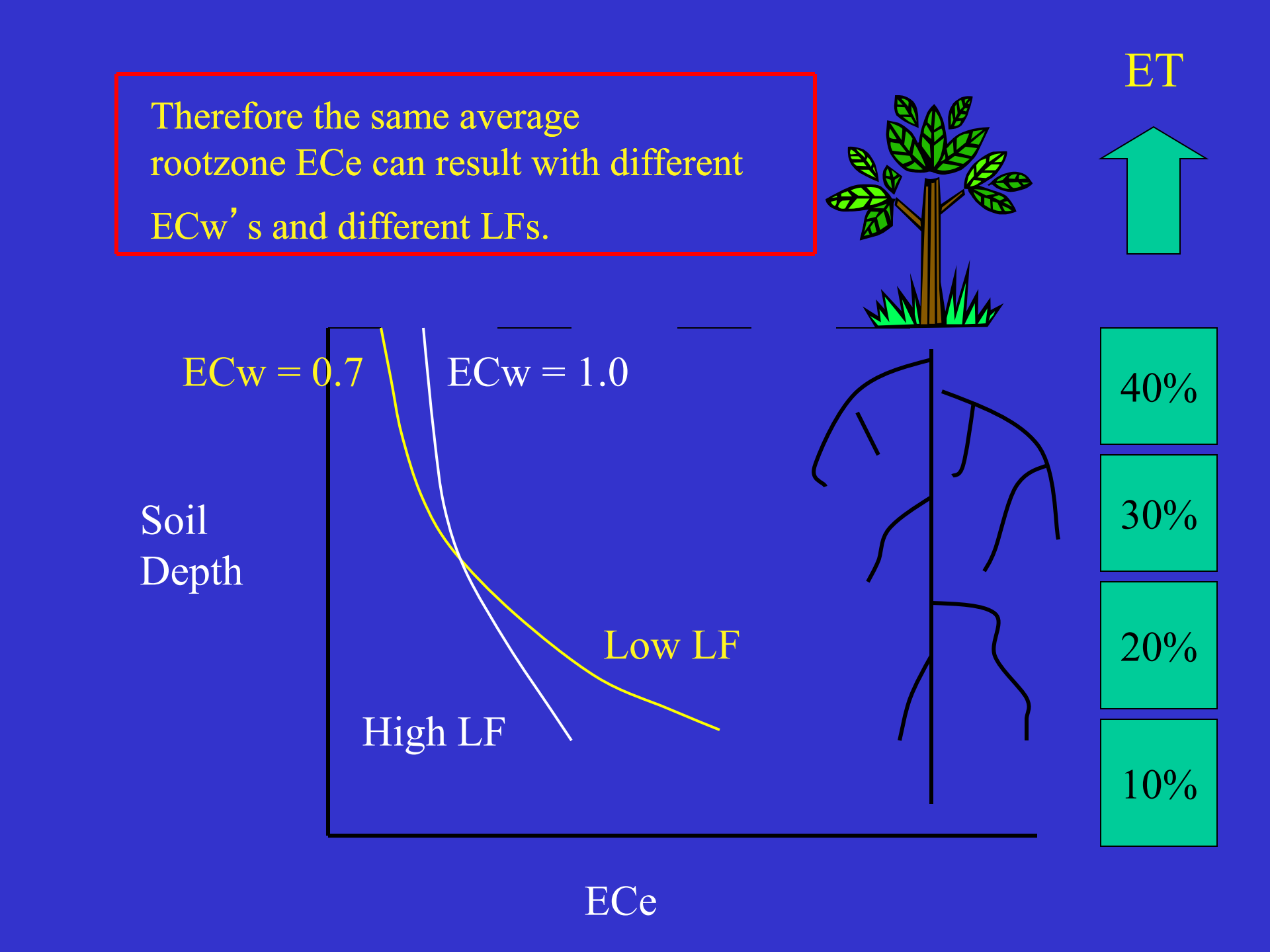
Steady-state model
(Ayers and Westcot, 1985)



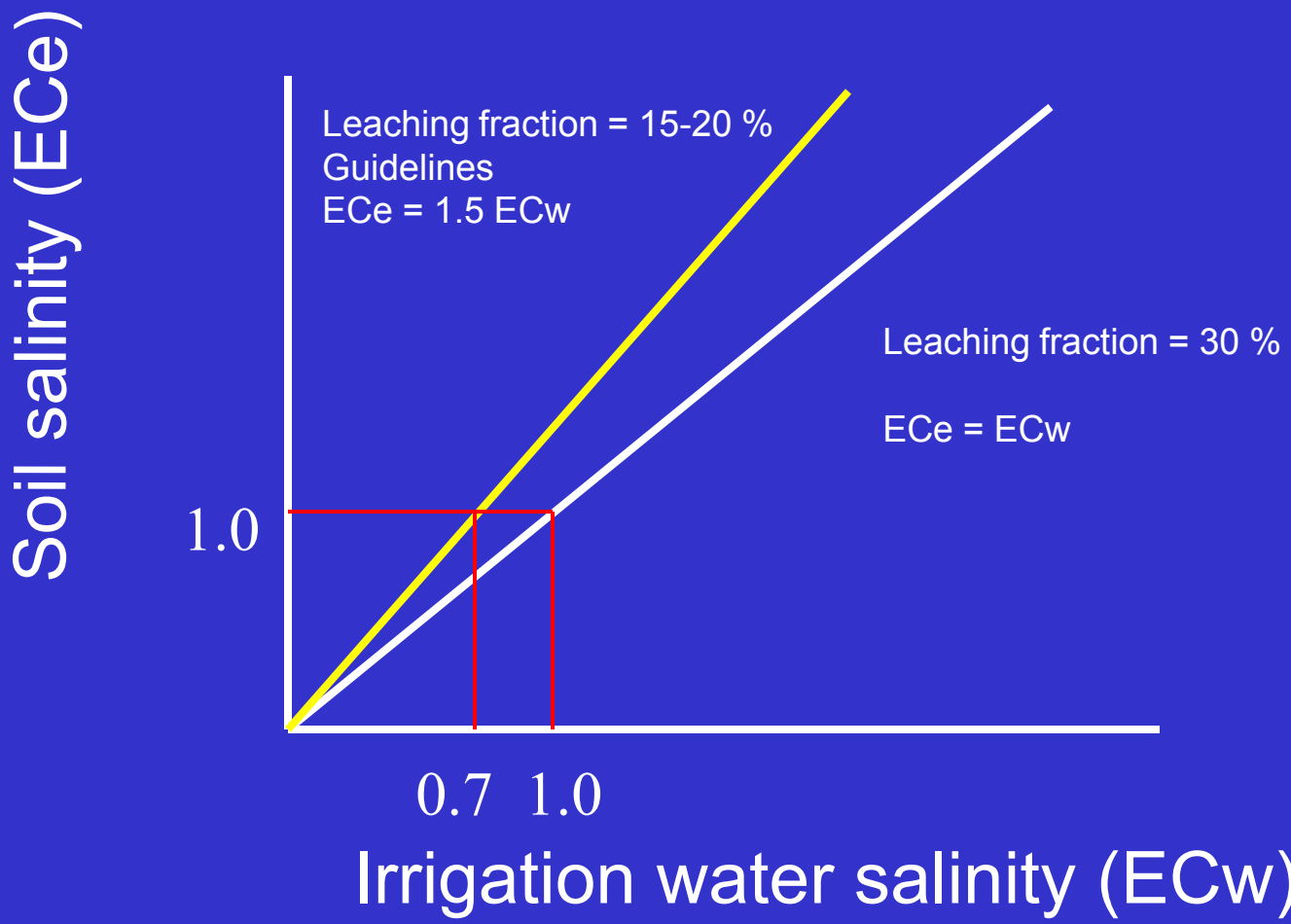
Average root zone salinity

$$ECsw=(ECw+EC_1+EC_2+EC_3+ECd)/5$$

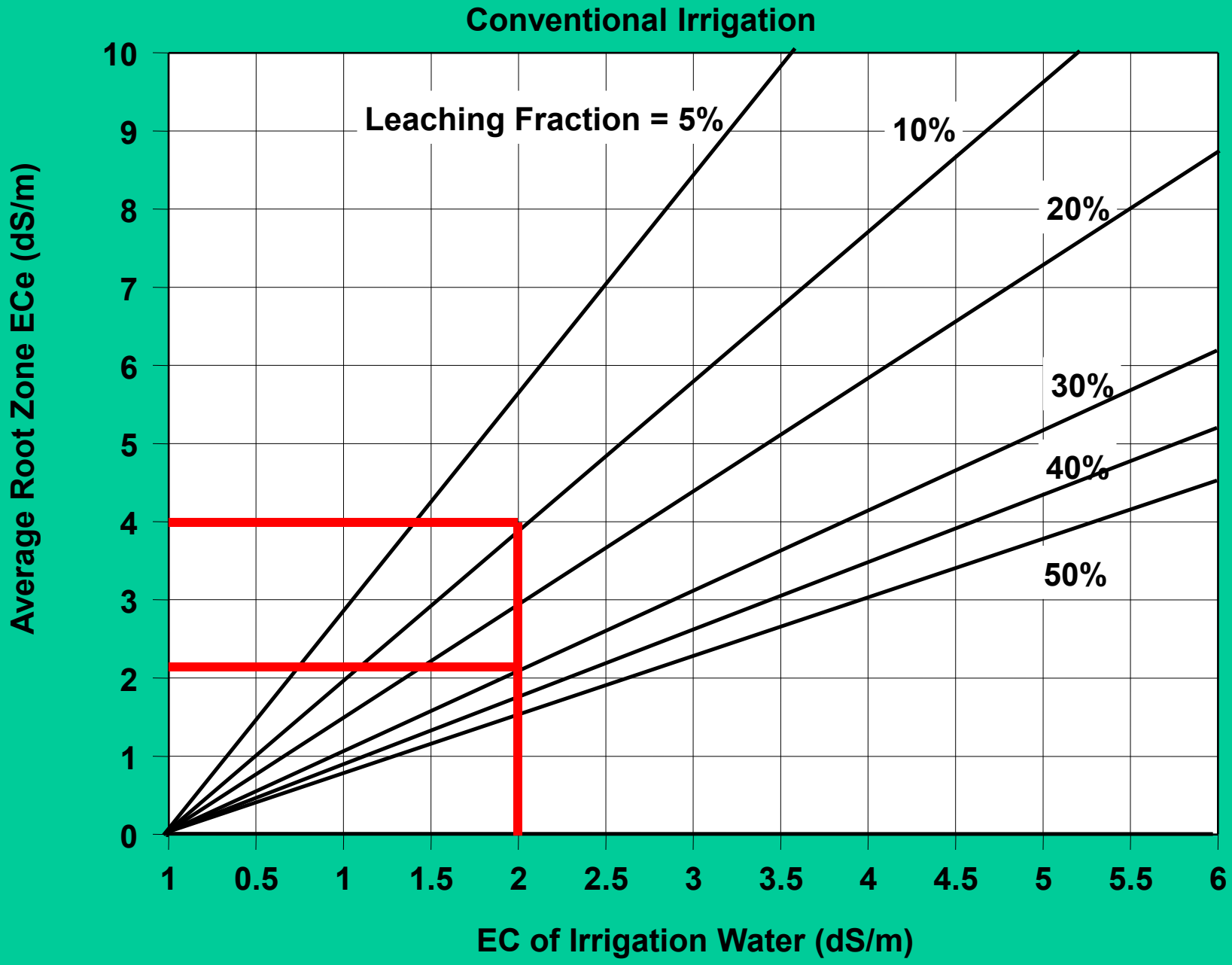
Therefore the same average rootzone ECe can result with different ECw's and different LFs.



Relationship between ECe and ECw



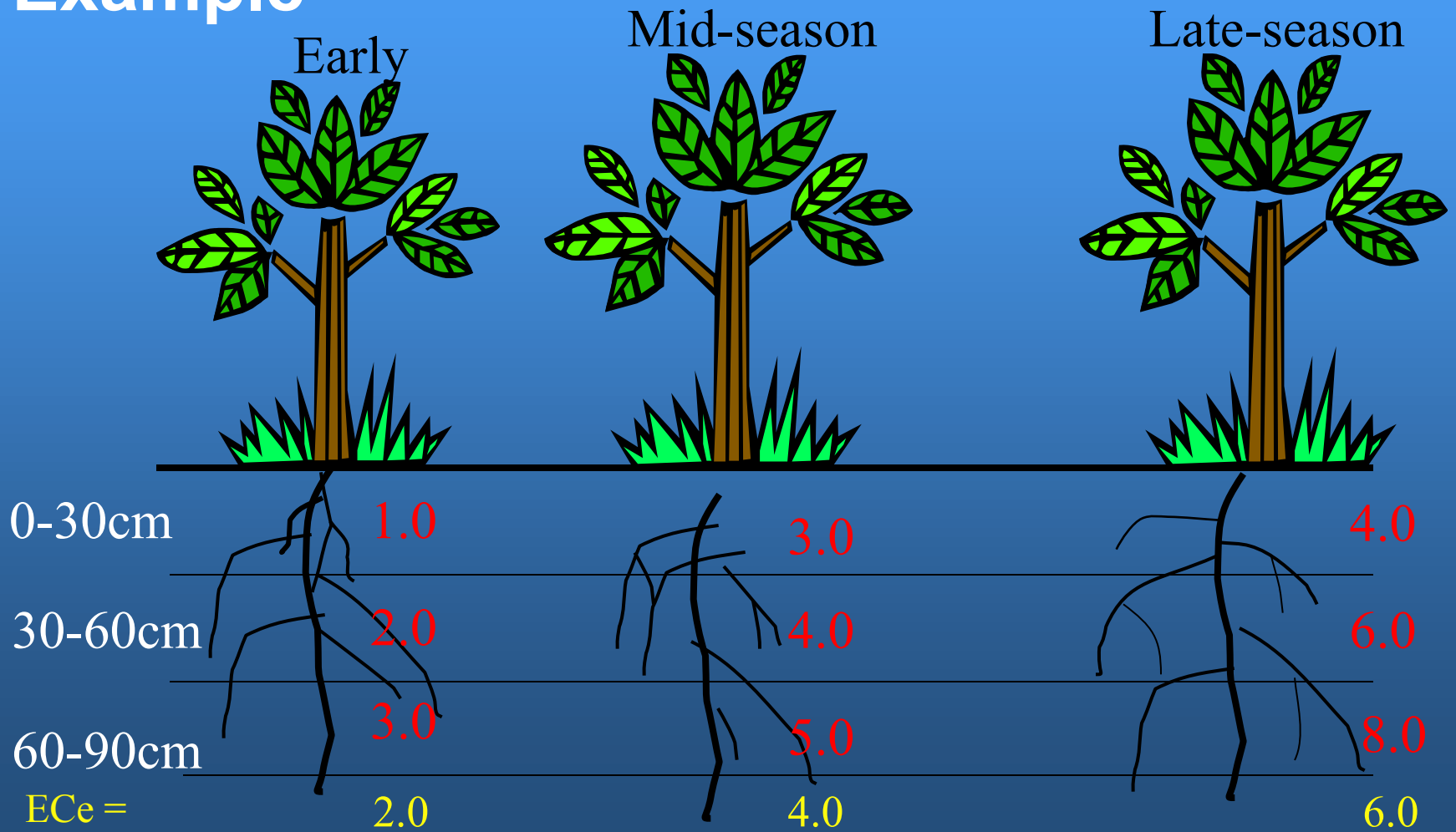
What is ECe if ECw is 2.0 dS/m and the LF is either 40 or 10 %?



Can we use this relationship
to estimate the leaching fraction?

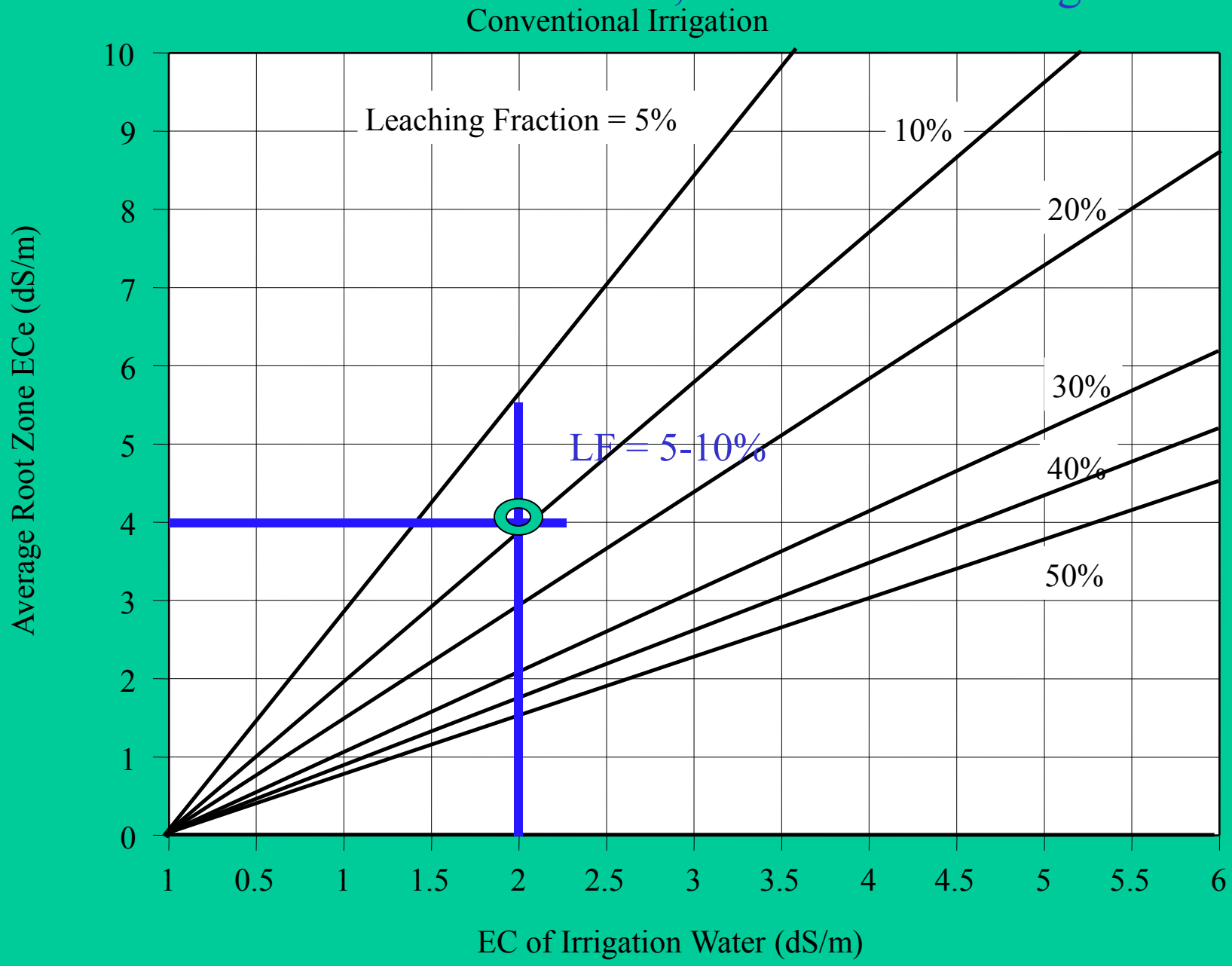
Seasonal average rootzone salinity (ECe)

Example

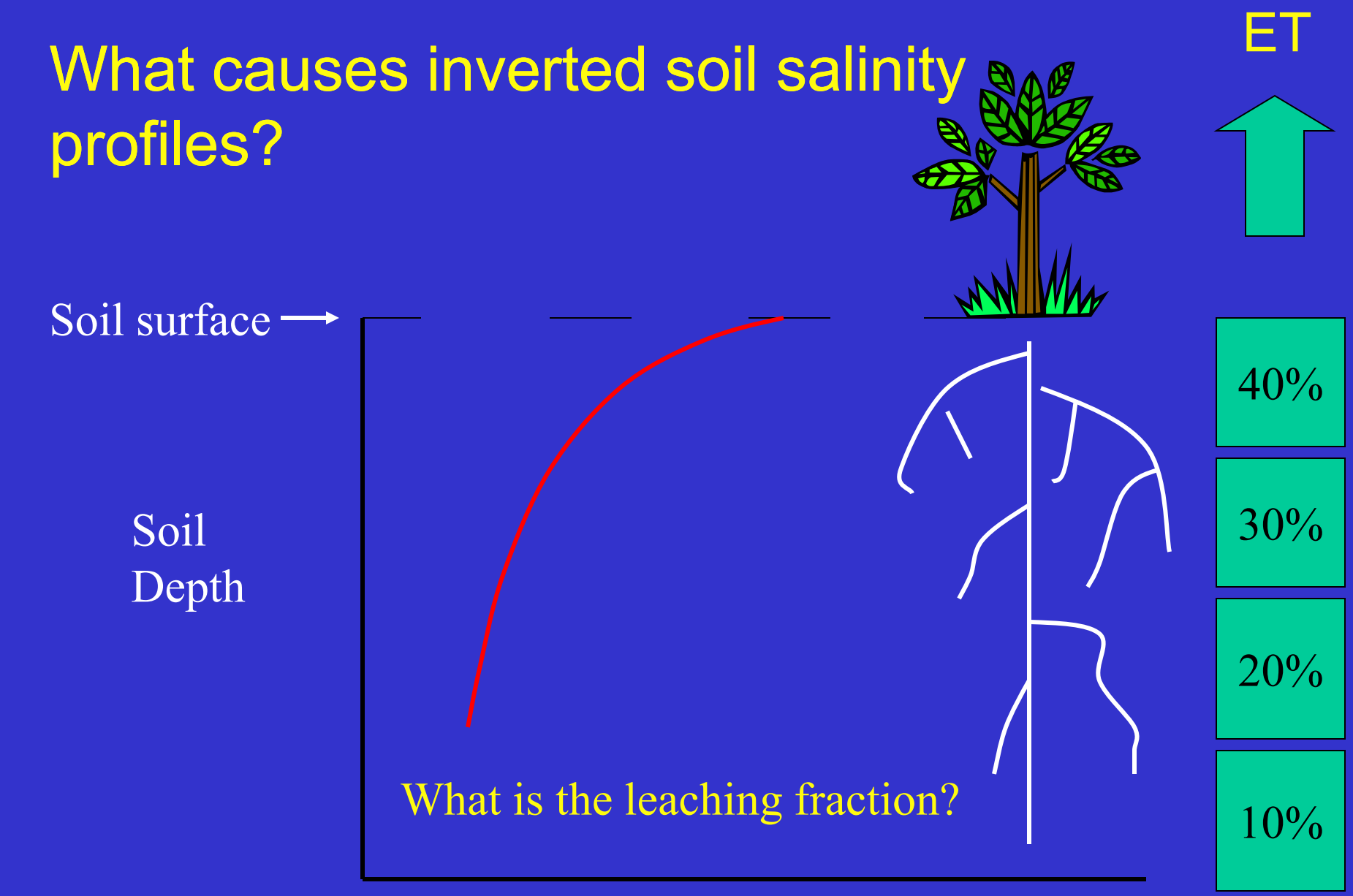


$\overline{ECe}$ = 2+4+6/3 = 4 dS/m Season average

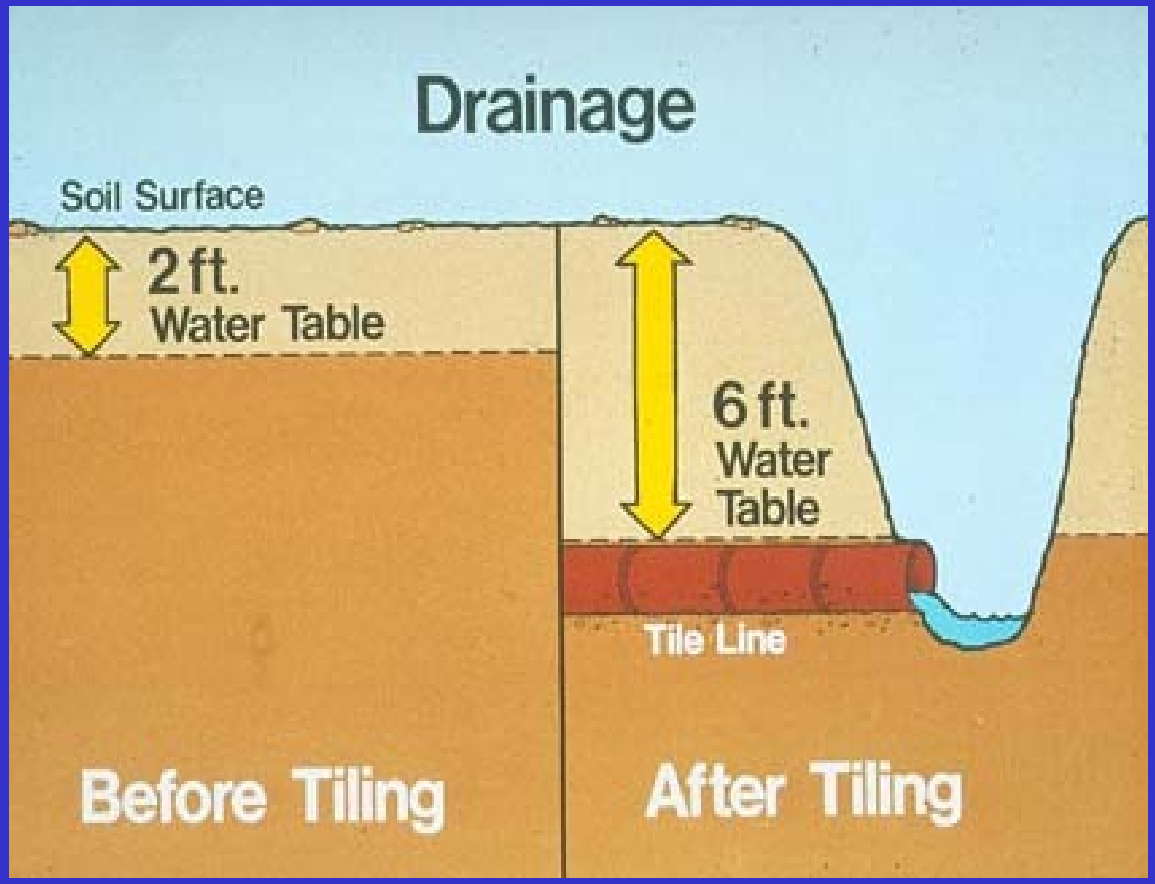
If ECw is 2 and the ECe is 4 dS/m, what is the leaching fraction?

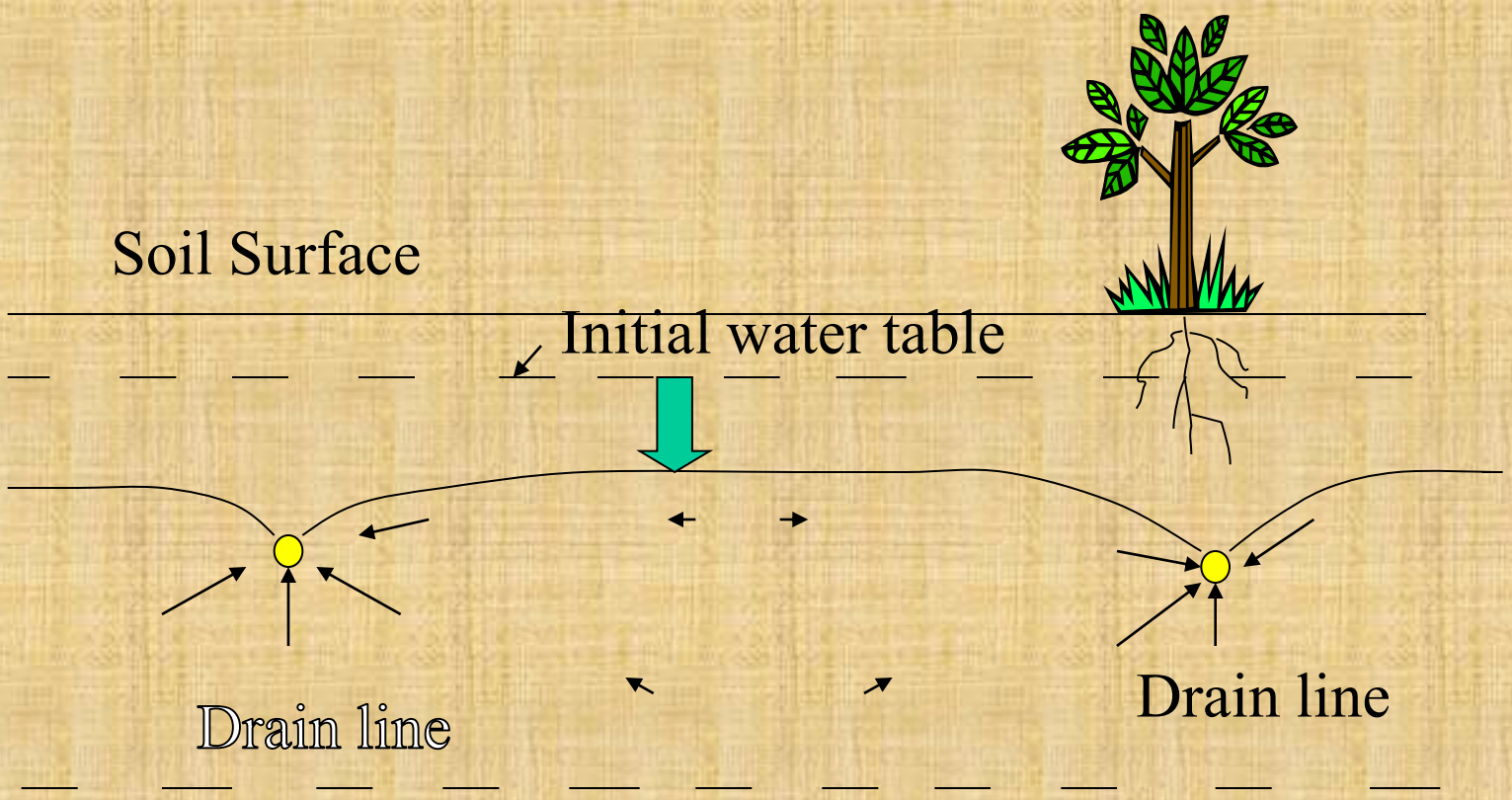


What causes inverted soil salinity profiles?

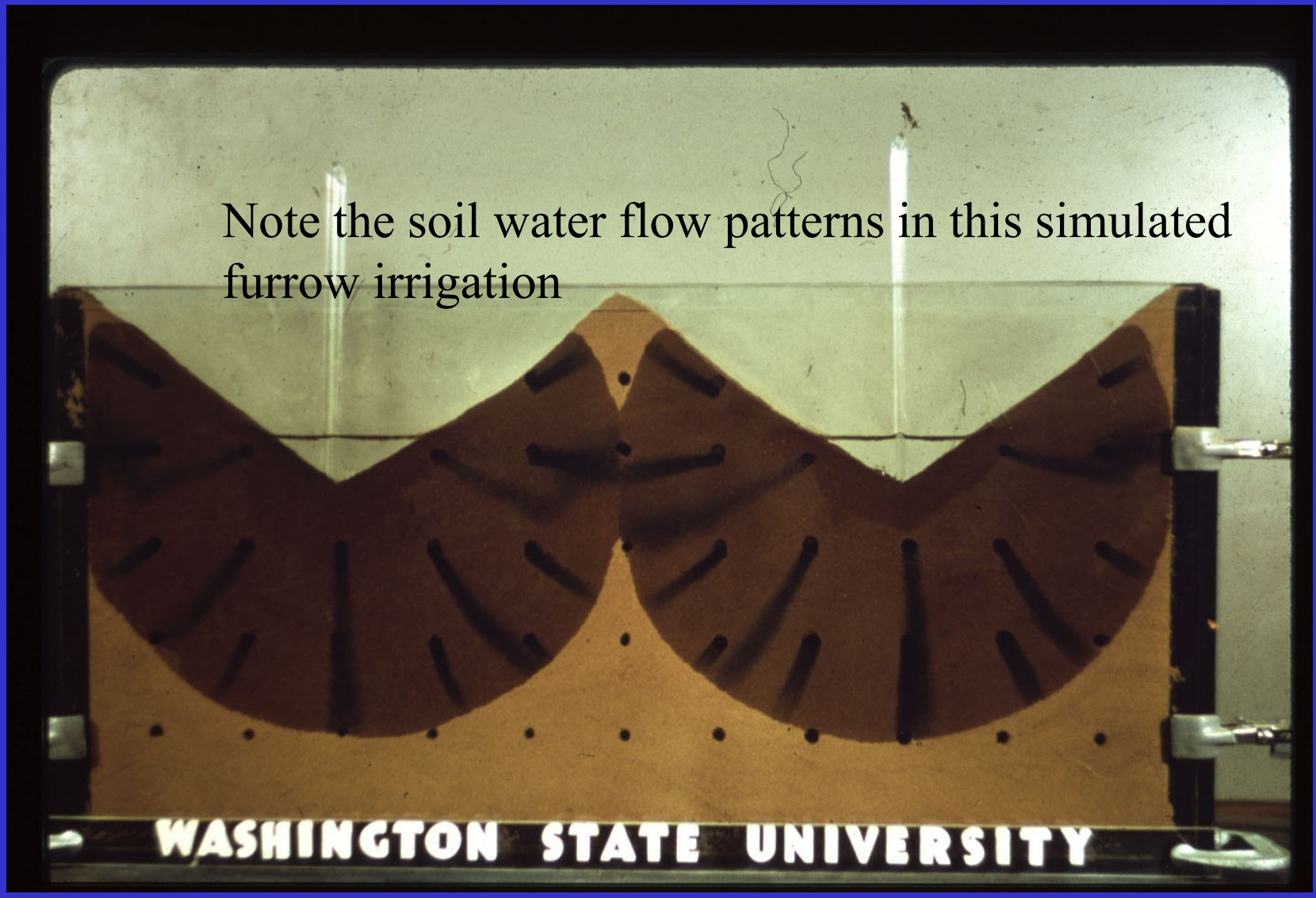


Water tables reduced by tiling





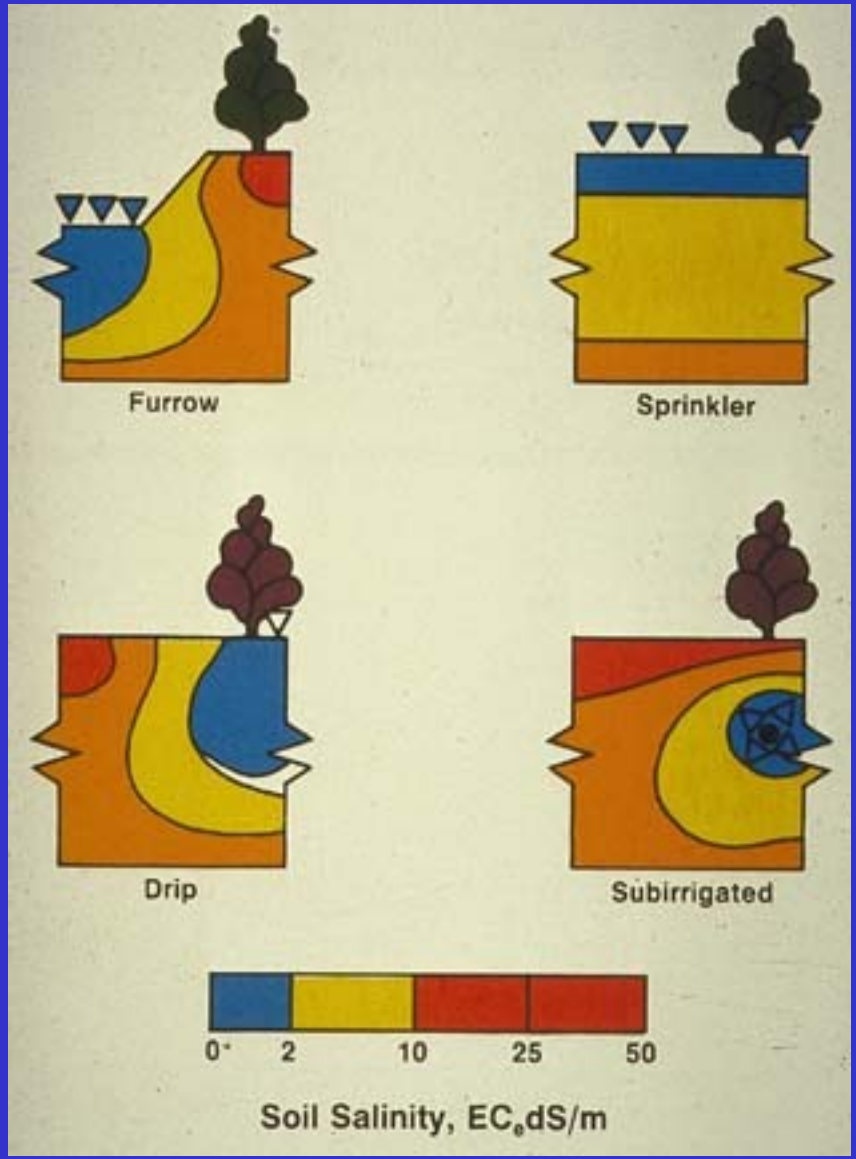
Managing high water tables

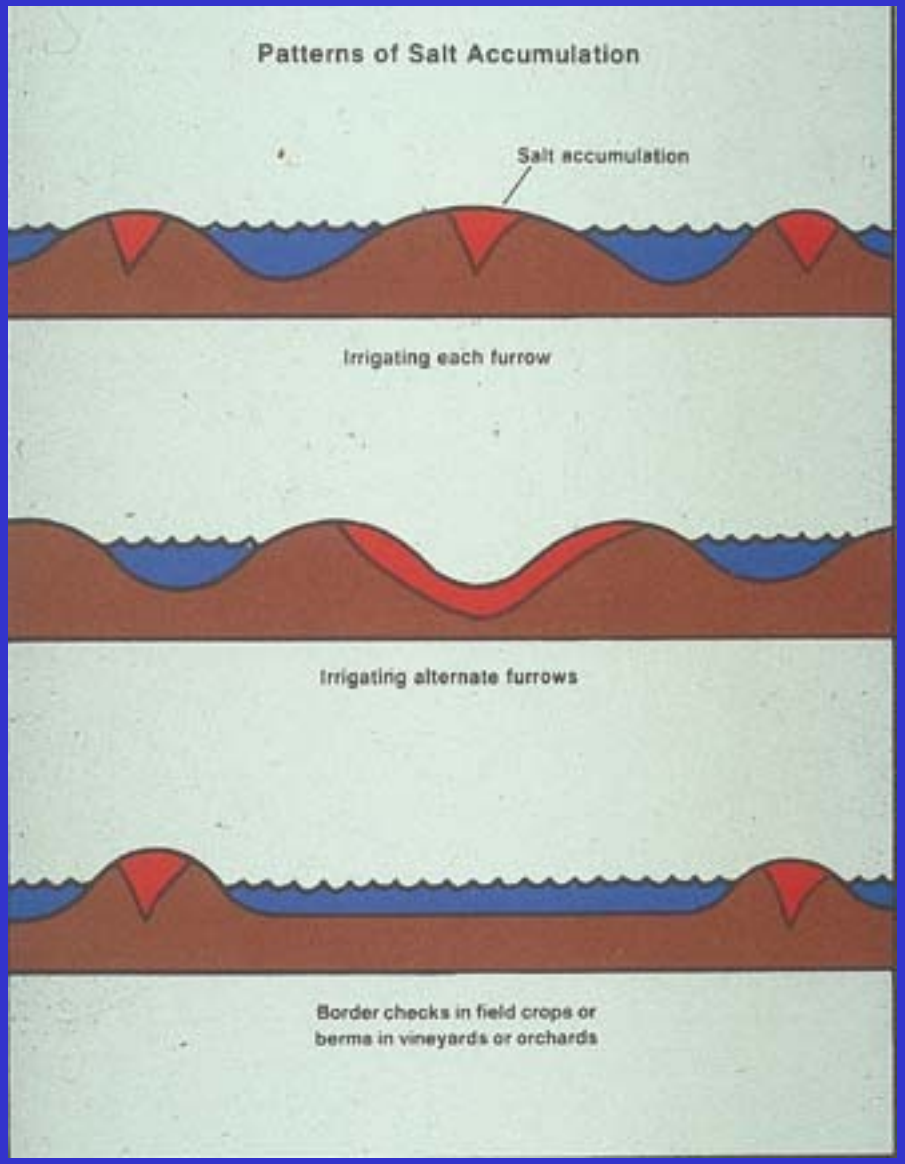


How salts move in the soil water

Salt distribution under different irrigation methods

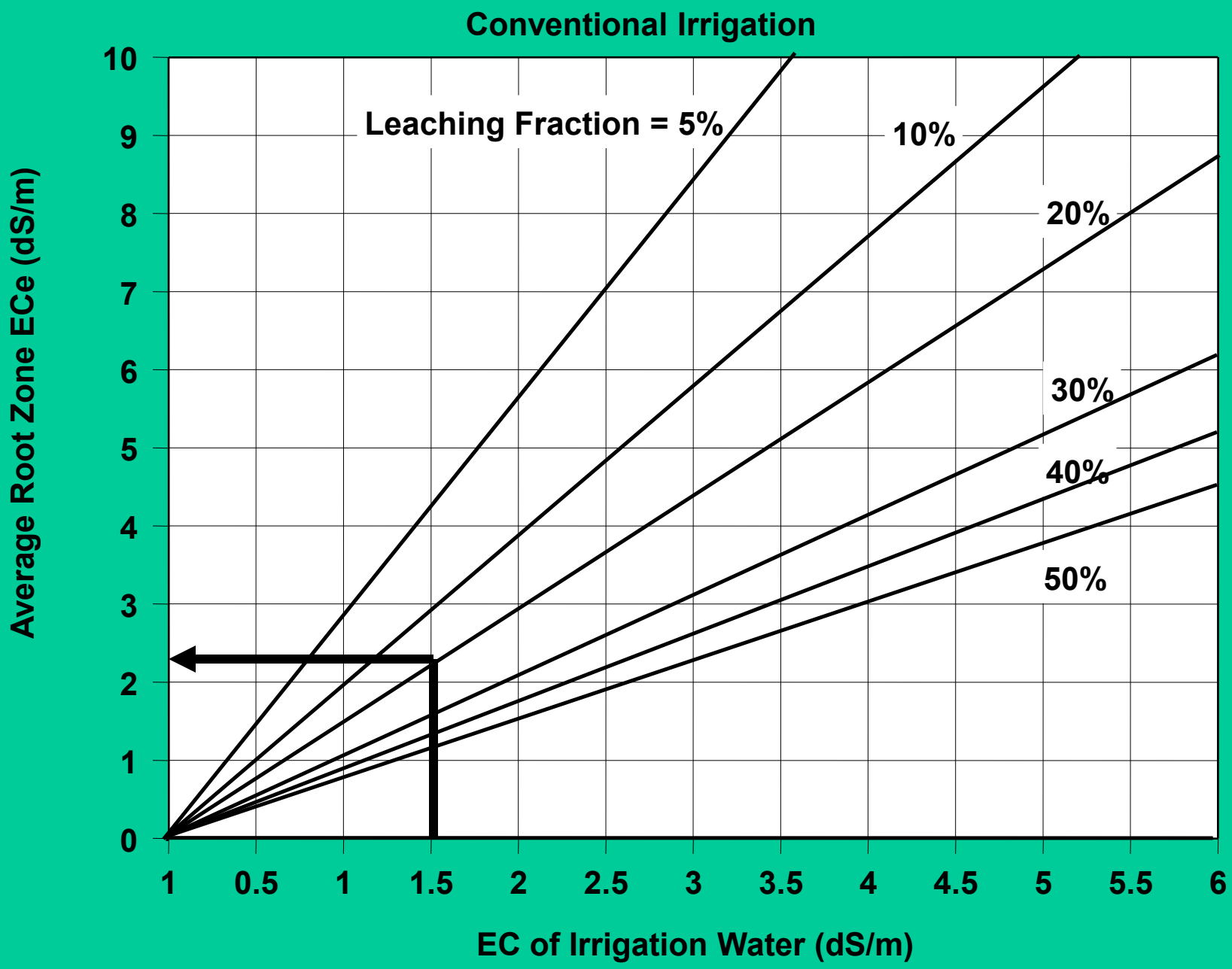
Salts move with soil water and concentrate as roots extract water and as water evaporates from soil surface




Patterns of Salt Accumulation
Salt accumulation
Irrigating each furrow
Irrigating alternate furrows
Border checks in field crops or
berms in vineyards or orchards

Example 1

- What would be the yield potential for potatoes if the ECw was 1.5 dS/m if a continuous LF of 20% can be achieved?


Conventional Irrigation
Leaching Fraction = 5%
10%
20%
30%
40%
50%
Average Root Zone ECe (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
EC of Irrigation Water (dS/m)

Example 1

- What would be the yield potential for potatoes if the ECw was 1.5 dS/m if a continuous LF of 20% can be achieved?
- ECw = 1.5 → ECe = 2.3 dS/m
- Y (%) = 100 - b (ECe - a)

"Crop yields as affected by salinity"
Threshold 'a' = 1.7 dS/m
Slope 'b' = 12 %/dS/m

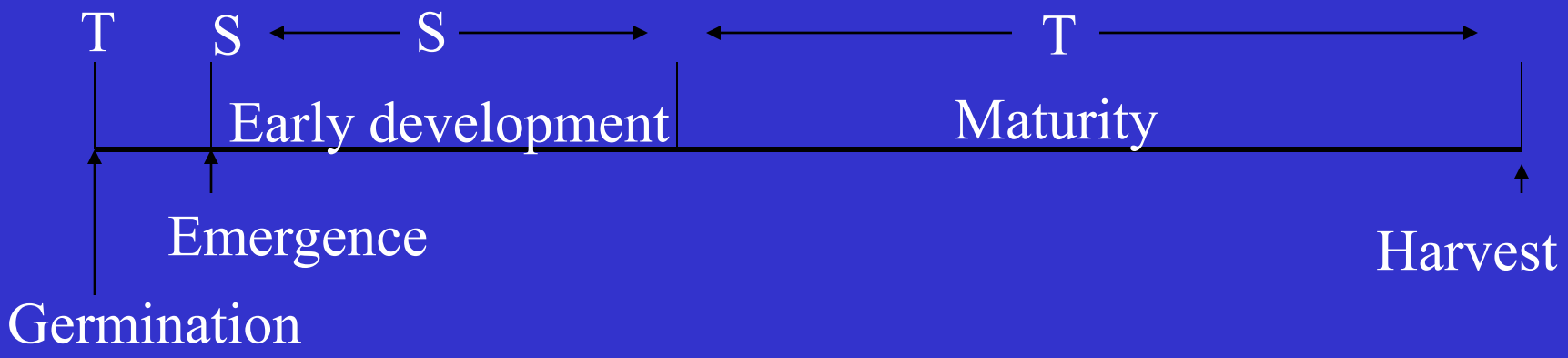
Example 1

- ECe = 4 dS/m
- Y (%) = 100 - b (ECe - a)
- Y (%) = 100 - 12 (2.3 – 1.7) =
- 93%

Water is suitable for long-term
irrigation of potato but yields will not be optimal

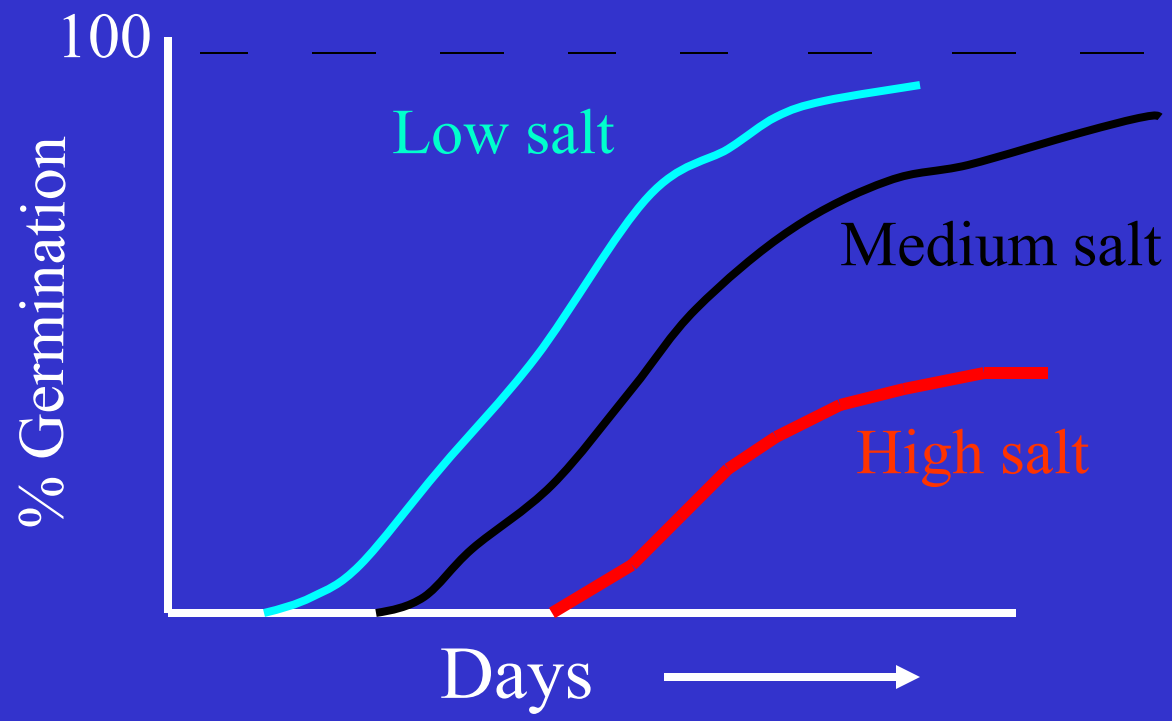
Are there particular growth stages where vegetables where are more sensitive or more tolerant to salinity?

Crop Sensitivity to Salinity in Relation to Stage of Growth

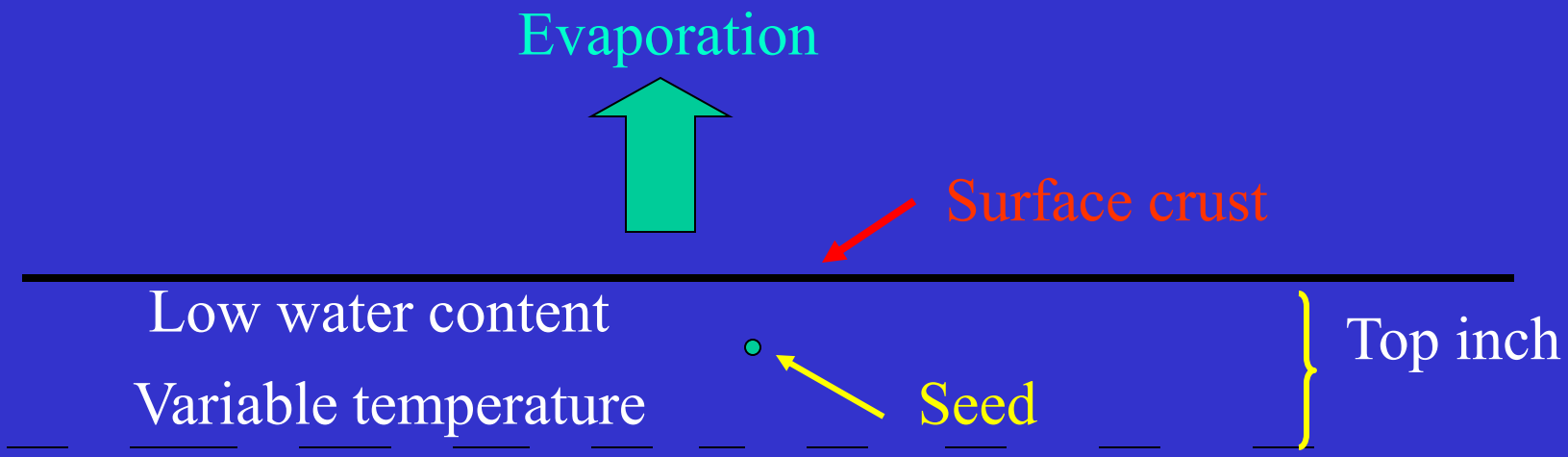


After Maas and Grattan, 1999

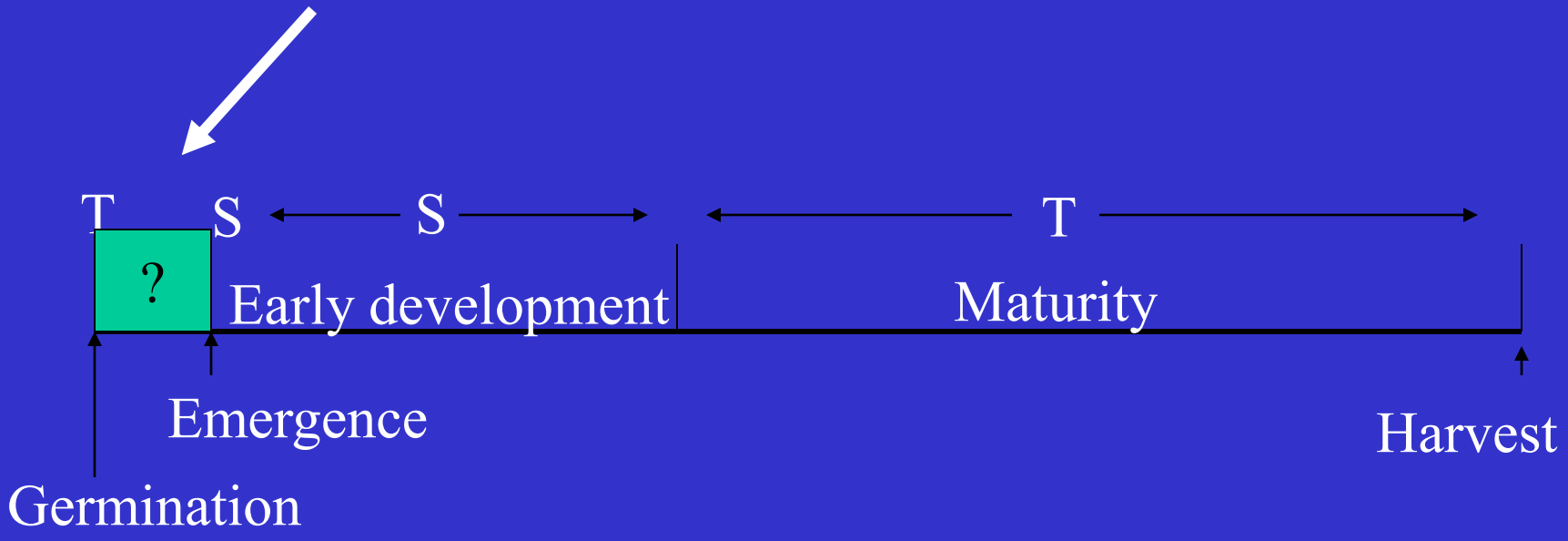
Salinity delays germination



Seed vulnerability near soil surface



More research is needed on physical, chemical and biological interactions in relation to seedling germination and emergence under saline conditions



Summary

- Crops vary in their tolerance to salinity
- Crops are affected by osmotic and specific ion effects
- Y (%) = 100 - b (ECe - a)
- Soil salinity typically increases with soil depth
- Salts move with the soil water and concentrate by ET
- If leaching is increased, crops can tolerate a higher salinity irrigation water
- Crops are generally more sensitive to salinity during early vegetative growth and tolerance progressively increases as the crop matures