Fertigation in Arid Regions and Saline Soils

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Silvertooth; IPI International Symposium on Fertigation; Optimizing the utilization of water and nutrients; Beijing, September 20-24, 2005

Fertigation in Arid Regions and Saline Soils - Outline

- Characterization of arid regions
- Saline and sodic soil conditions
- Crop specific water requirements
- Crop nutrient requirements
- Integration and system management
  - Water use
  - Nutrient uptake
  - Soil salinity/sodicity

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General Overview

- **Alkaline and salt-affected soils found mostly in arid and semi-arid regions**
  - **involves more than 1/2 of earth's arable land**
  - **<500 mm annual precipitation (<20 inches)**
  - **consist of very diverse groups of conditions**
    - **plant and animal communities**
    - **biological diversity**

General Overview (cont.)

- **Soils of arid and semi-arid areas are mostly alkaline**
  - **some are also salt or sodium (Na) affected**
  - **rainfall (and snowfall) insufficient to leach out base forming cations (Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}, etc.)**
    - **basic cations released as rocks and minerals weather**

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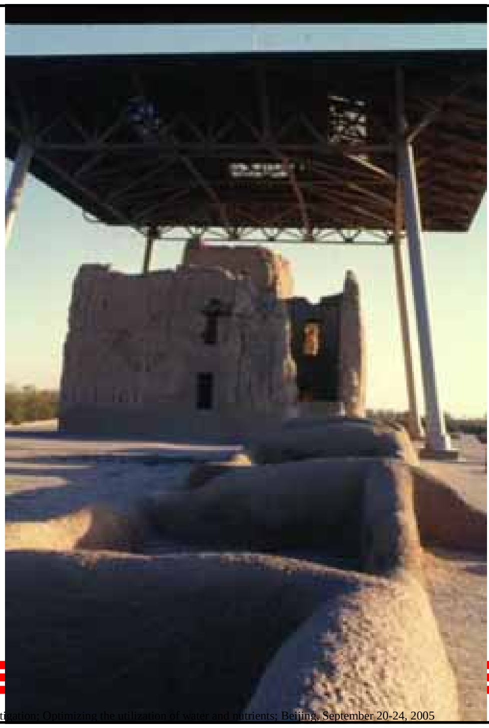
General Overview (cont.)

- **Soils in these regions have played a unique role in history**
  - **rise and fall of several ancient civilizations tied to irrigation and subsequent mismanagement**
  - **knowledge of previous mistakes of earlier civilizations can lead to prevention of repeating errors in management for the future**



Water Quality

- **Quality of irrigation water is also critical**
  - **can contribute significant amounts of salt**
  - **without proper drainage and management- soil salinity can increase to intolerable levels**
    - **leads to chemical and physical problems**

Saline Soils

- **EC_e > 4 dS/m (saline conditions)**
- **ESP < 15**
- **$SAR_e \leq 13$**

- **crop growth can be adversely affected by excesses of both salt and Na**

Saline Soils (cont.)

- **Poor physical condition is commonly not a problem on saline soils**
  - **soluble salts help <u>prevent</u> dispersion**
    - **good aggregate stability and aeration**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Sodic Soils

- $EC_e \leq 4$ ds/m (non-saline)
- ESP > 15 (sodic)
- $SAR_e \geq 13$ (sodic)

- sodic soils are the most troublesome of the three basic conditions described here

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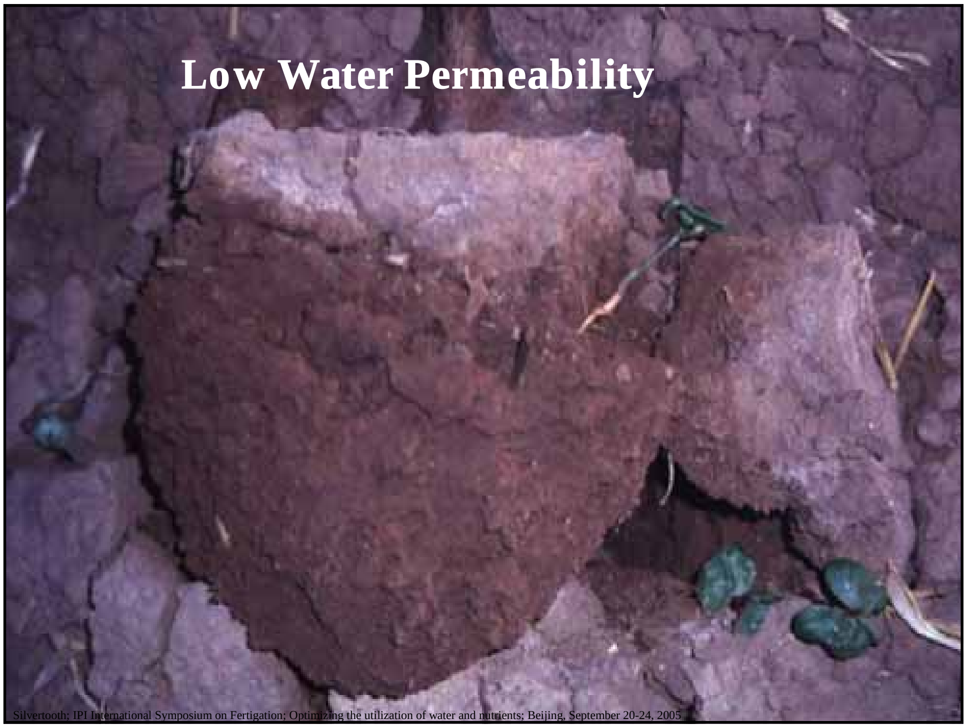

Saline-Sodic Soils

- **EC_e > 4 ds/m (saline conditions)**
- **ESP > 15 (sodic conditions)**
- **$SAR_e \geq 13$ (sodic conditions)**

- **crop growth can be adversely affected by excesses of both salt and Na**

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Management of Saline and Sodic Soils

- Must develop a salt balance approach
- understanding of amount and nature of mobile salts being added to and removed from soils
- must know about the quality of irrigation water
- quantity of irrigation water being applied
- soil drainage status

Leaching Requirement (LR)

- Leaching Requirement - amount of water needed to remove excess salts from saline soils
  - LR depends on:
    - characteristics (tolerance) of crops being grown
    - irrigation water quality
    - soil characteristics

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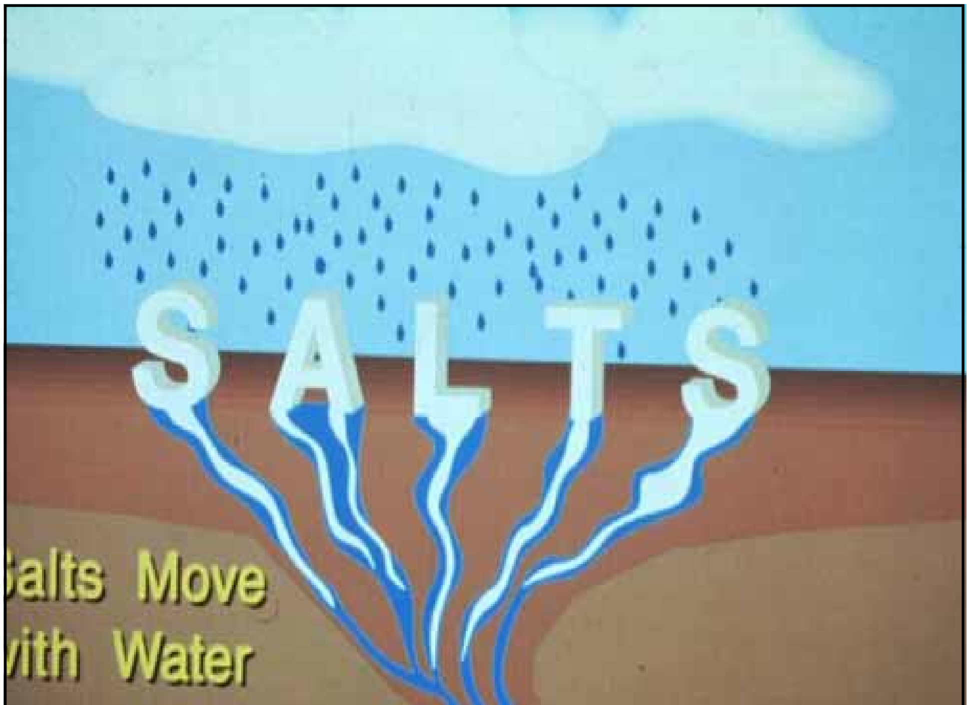


Leaching Requirement (cont.)

- **LR (approximate) = ratio of salinity of irrigation water (EC_w) to maximum possible salinity of the soil solution for the crop to be grown (EC_{dw})**
  - **LR = EC_w/EC_{dw} (general approximation)**
  - **LR is the water added in excess of that needed for the crop**
  - **if EC_w is high and crop to be grown is very salt sensitive, a very large LR would result**

Alternate Approach to LR Calculation

$$LR = \frac{EC_w}{5(EC_e) - EC_w}$$

Where:

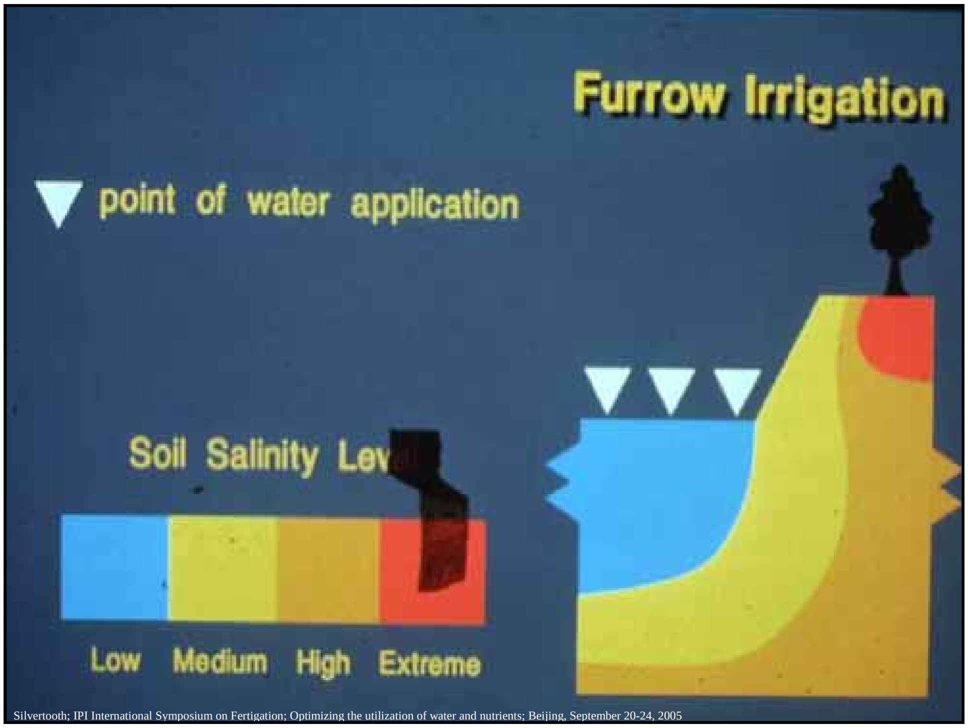
EC_w = salinity of applied irrigation water (dSm)

EC_e = maximum soil salinity (average) tolerated by the crop

AW = applied water (depth) needed

$$AW = \frac{ET}{1 - LR}$$

ET = total annual crop demand (i.e. mm / year)



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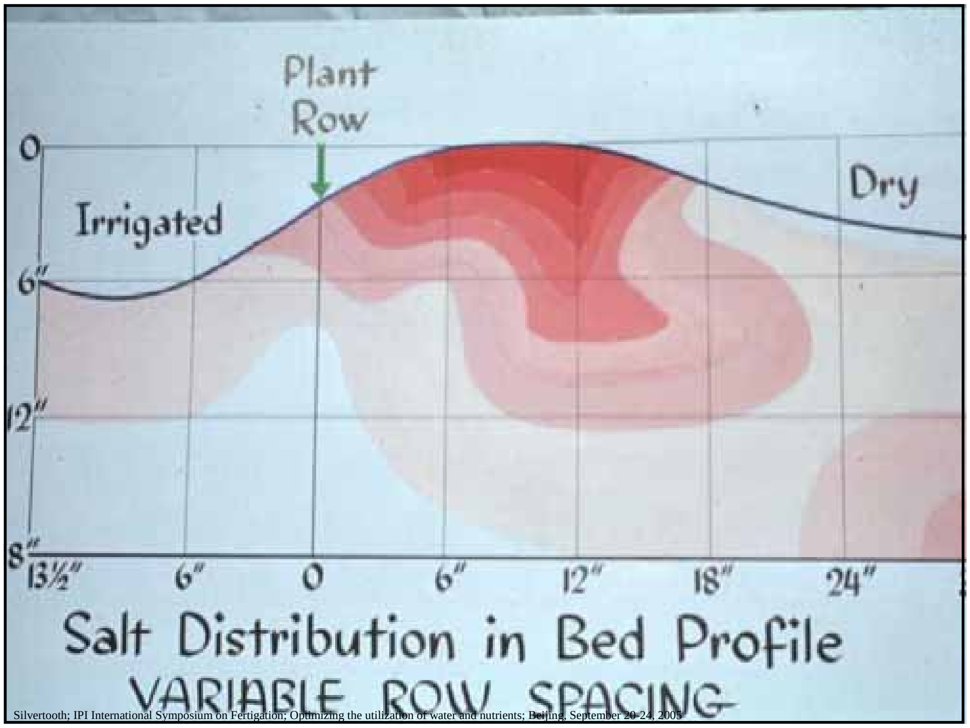
Plant Row
Dry
Irrigated
0
6"
12"
8"
13½"
6"
0
6"
12"
18"
24"
Salt Distribution in Bed Profile
VARIABLE ROW SPACING
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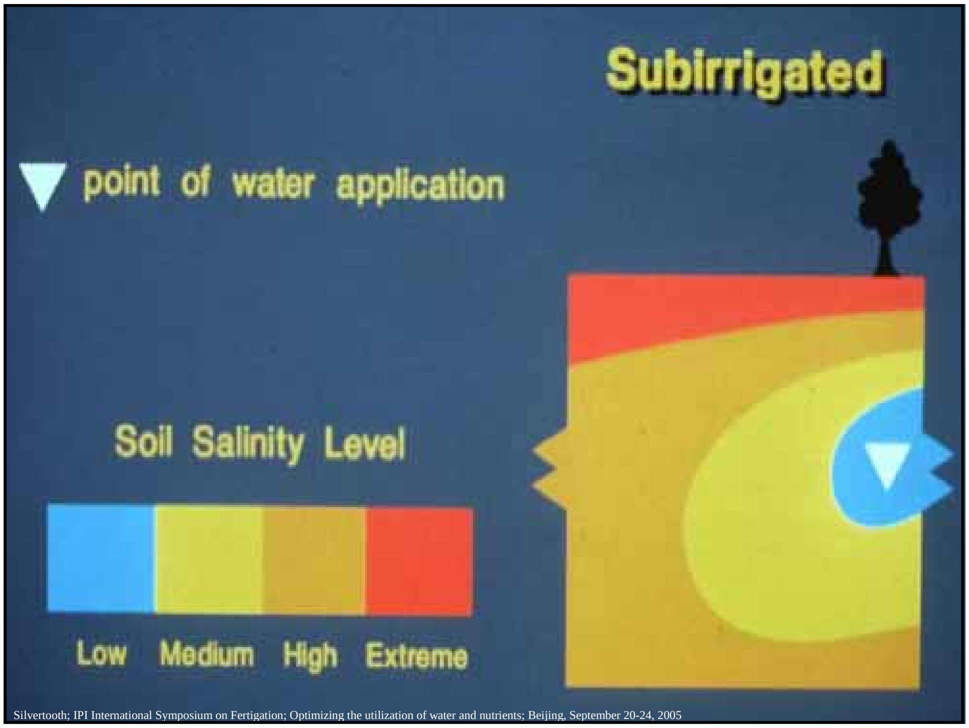
Subirrigated
point of water application
Soil Salinity Level
Low
Medium
High
Extreme
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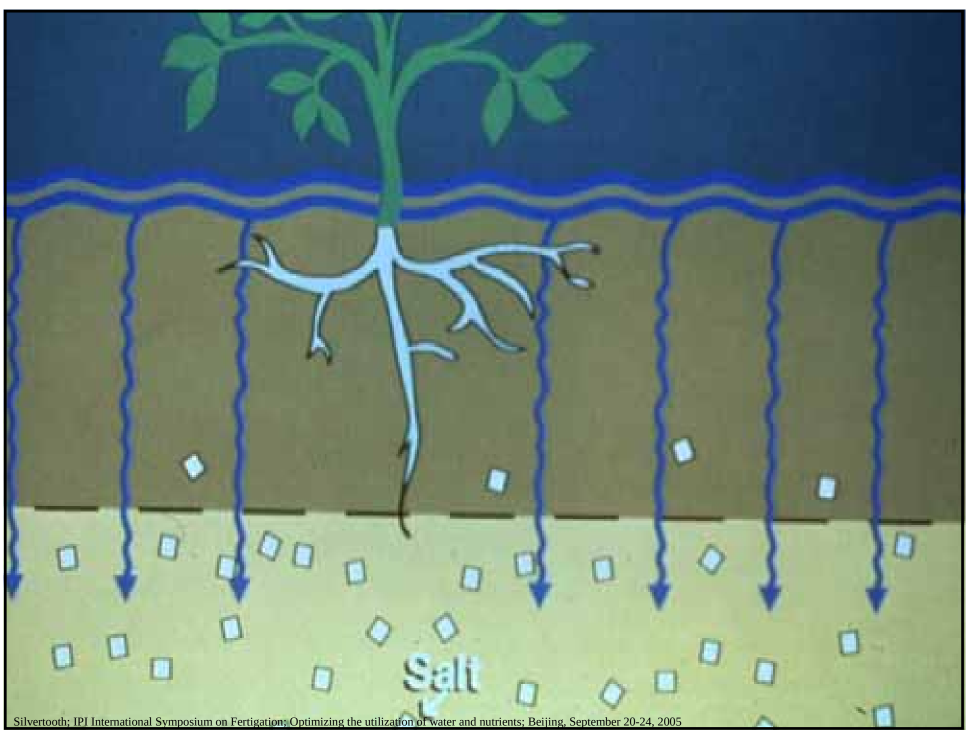
Salt
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Reclamation of Saline-Sodic and Sodic Soils (Example)

1. $2Na\text{-}X + CaSO_4 = Ca\text{-}X + Na_2SO_4$
2. Leaching of soluble Na_2SO_4 in soil solution

NOTE: leaching is a percolation process that only occurs under saturated soil conditions

Ca^{2+} or H^+ ions are most effective in accomplishing a replacement of Na^+ on the exchange complex

Gypsum ($CaSO_4 \cdot 2H_2O$) practical source of Ca^{2+}

Sulfur and Sulfuric Acid

- **S and H_2SO_4 can be very effective when ample levels of free carbonate are present. (high free $CaCO_3$ levels and/or sodium bicarbonate)**
- **S upon biological oxidation yields sulfuric acid**

Integration – System Management

- **Understand crop phenology**
  - **Crop growth and development**
- **Establish growth guidelines as a function of heat unit accumulations**
- **Integration:**
  - **Crop development**
  - **Water use**
  - **Nutrient requirements**

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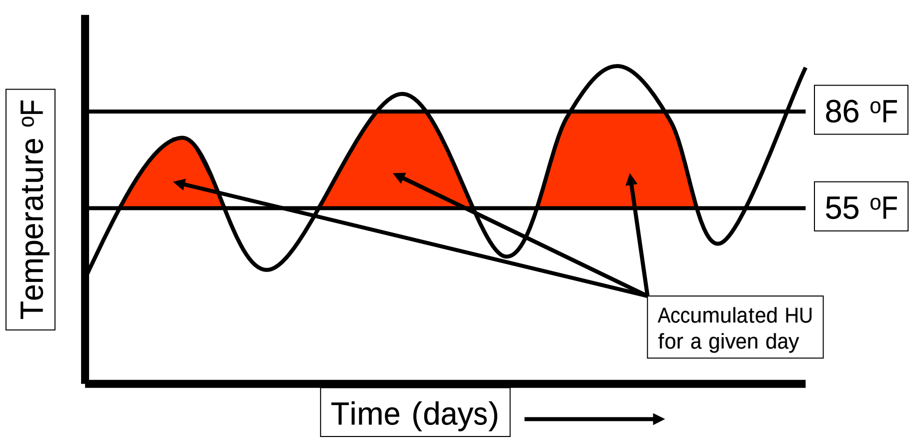
Heat Unit Concept



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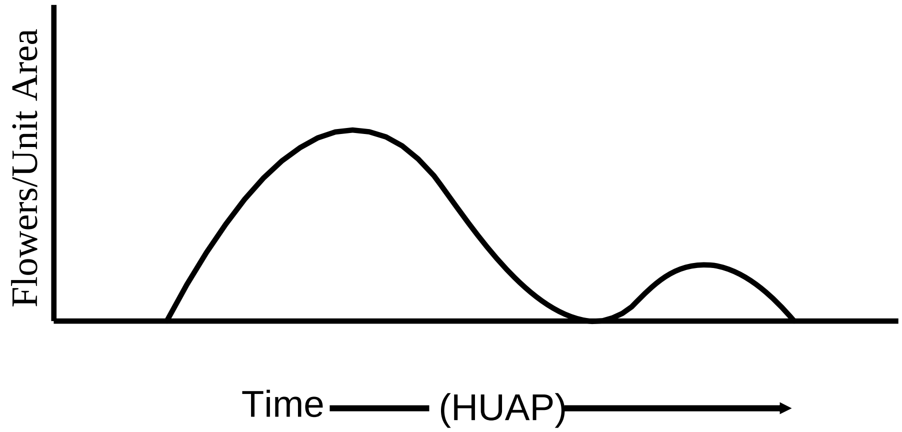
General Cotton Fruiting Cycle



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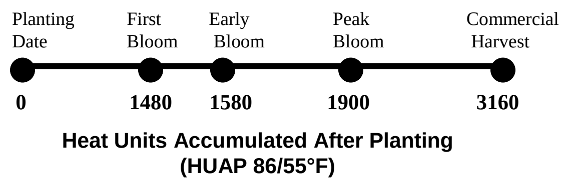
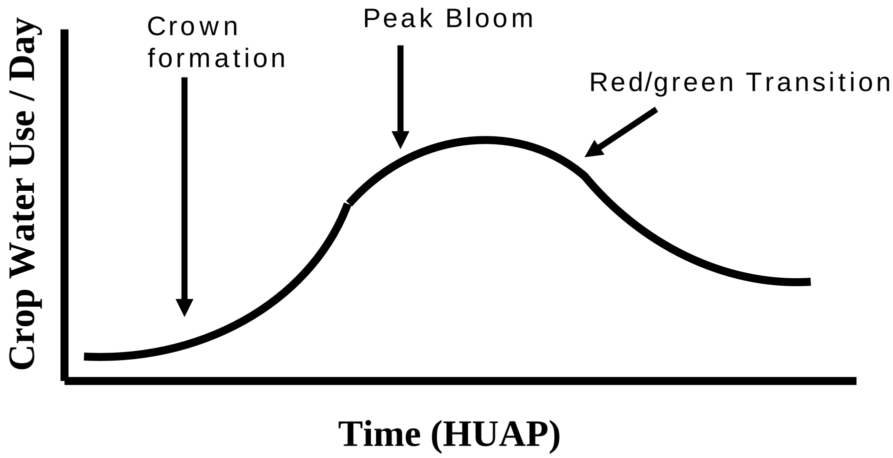
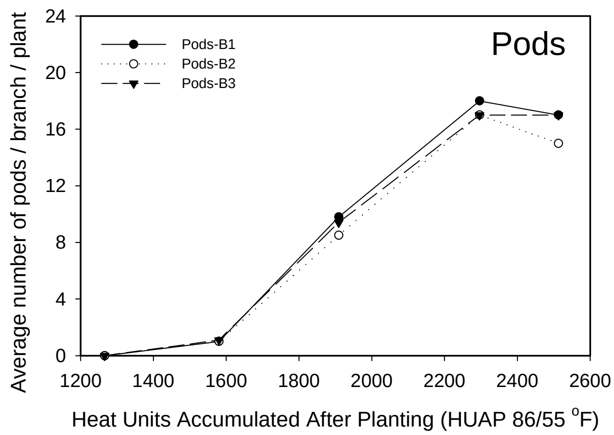
General green chile plant development as a function of heat units



Consumptive Water Use - Chiles



Pod development as a function of heat units for green chiles (var. AZ 20).



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Plant Available Water (PAW) - Chile plant optimums

- **Optimum PAW range for chile plants**
  - **80% - Field Capacity (FC)**
- **General PAW range**
  - **70% - FC**

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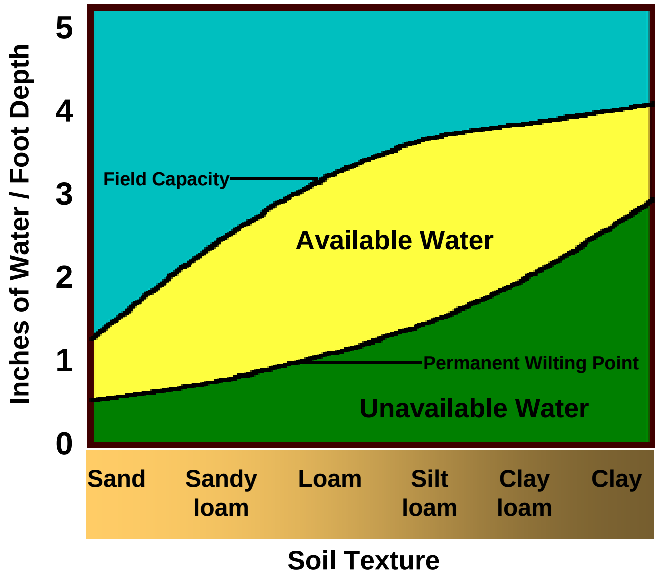
Soil Water



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Water Use - Efficiencies

Assume: C.U. = 36 inches of water

Irrigation Efficiencies

80% - 45 inches

70% - 51 inches

60% - 60 inches

50% - 72 inches

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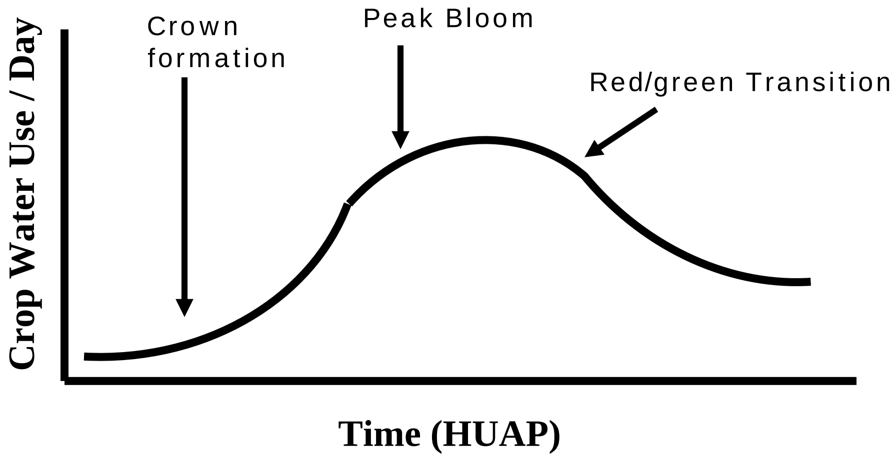
Consumptive Water Use



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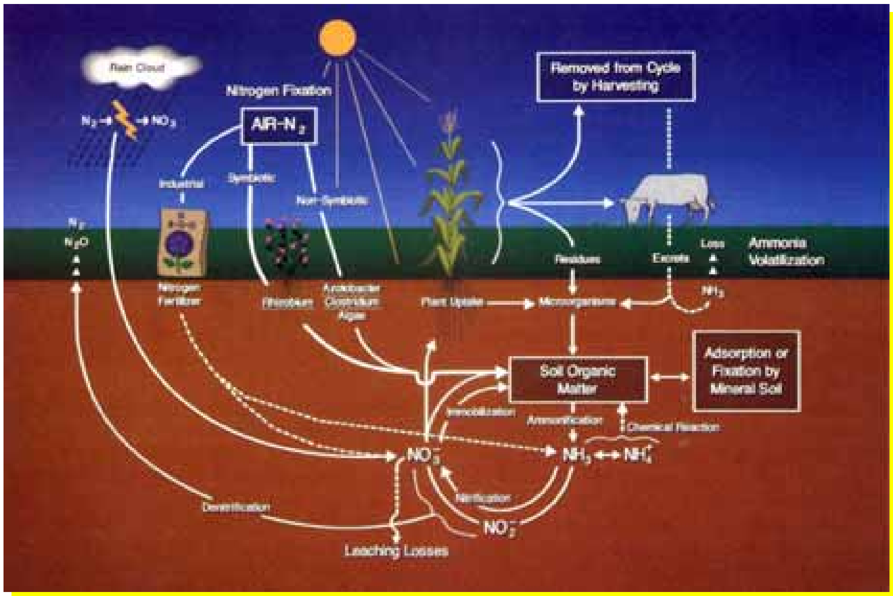
Nitrogen Cycle



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Optimal N Management

1. Use <u>realistic</u> yield goal
   - ~32 kg N / bale (216 kg/bale) cotton
   - sets upper limit for crop N needs

   - Ex. 6 bales/ha = yield goal
     - Target ~ 192 kg/ha total
     - Assumes high fert. N

Optimal N Management, cont.

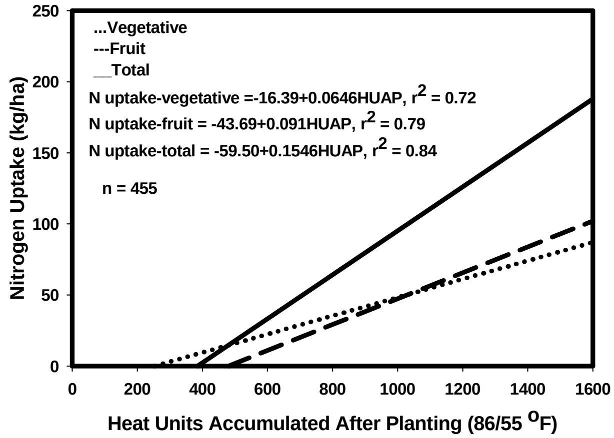
2. Take into account residual soil N (NO_3 –N)

   - also irrigation water NO_3^- - N

   2.7 X ppm NO_3^- -N = lbs. N/acre ft. water

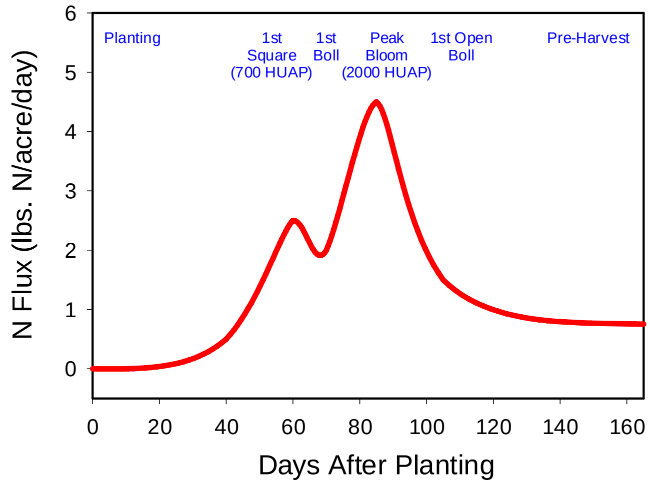
   - subtract from total N needs

Melon nitrogen (N) uptake as a function of HUAP, overall means, 15 locations (AZ, 2003-2004).

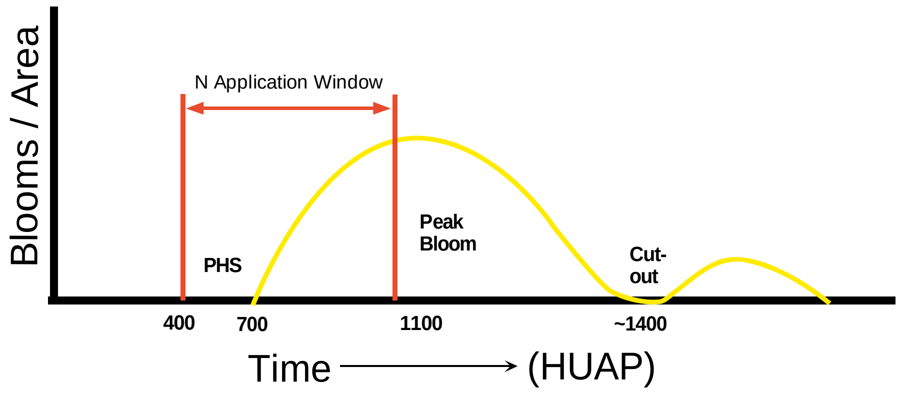


2003-2004 Melon nitrogen uptake as a function of HUAP.

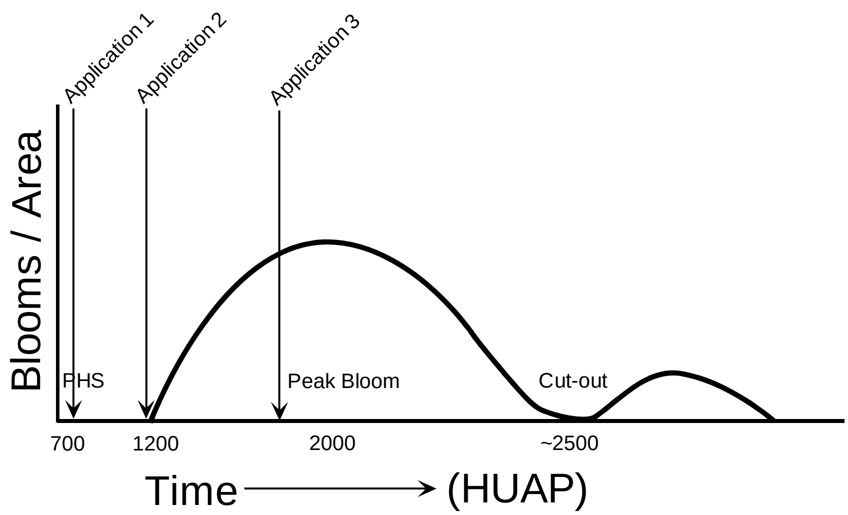
Nitrogen Uptake / Flux Curve for Cotton



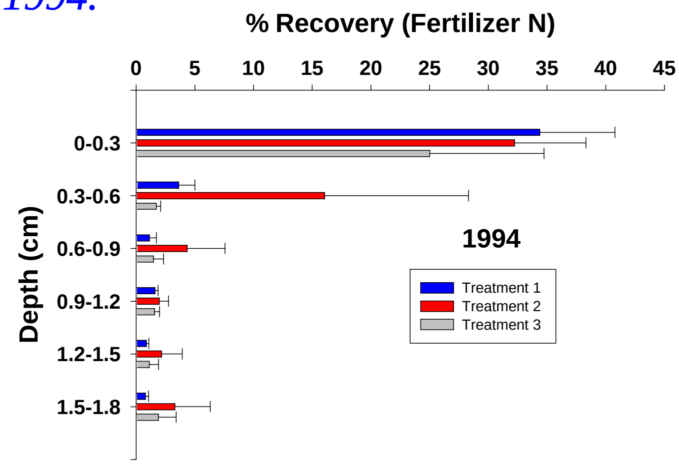
General N Application Window



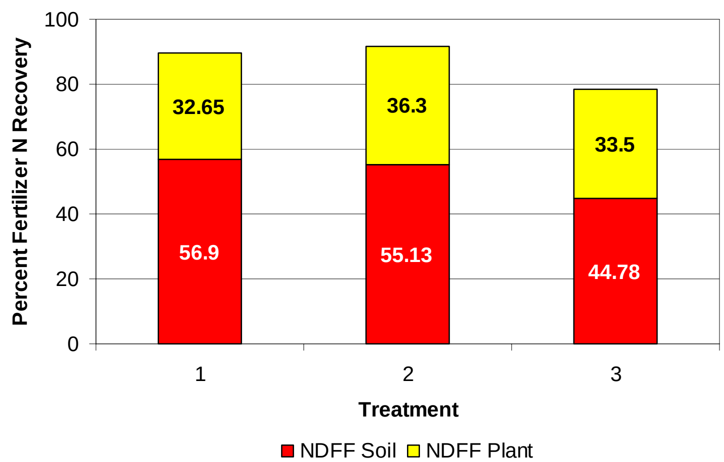
^{15}N Applications



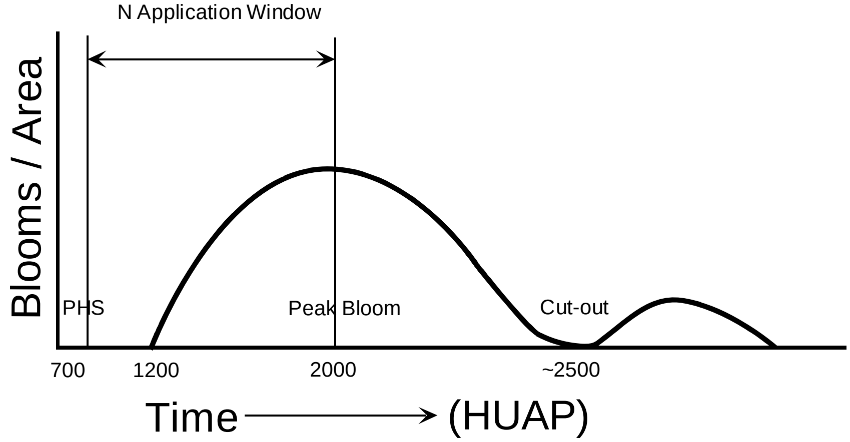
Fertilizer N recovery in the soil profile, by depth among treatments, Marana, AZ, 1994.



Percent total (plant + soil) fertilizer N recovery, Marana, AZ, 1994-95.



General N Application Window



Consider System Efficiency

- **Irrigation system efficiency**
  - **Delivery of water and nutrients**
- **Conservation of nutrients in the water**
  - **Precipitation**
  - **Volatilization**

Addition of Anhydrous Ammonia to Irrigation Water (reactions)

$NH_3 + H_2O = NH_4OH$

$NH_4OH = NH_4 + OH$

$OH^- + HCO_3^- = CO_3^{2-} + H_2O$

$Ca^{2+} + CO_3^{2-} = CaCO_{3(s)}$

Objectives – N Volatilization

- **Examine the potential loss of fertilizer N from irrigation waters**
- **Examine the effects of temperature on the process of volatilization**
- **Examine the effects of water quality on potential N loss from irrigation water**
  - **Which quality parameters have highest influence**

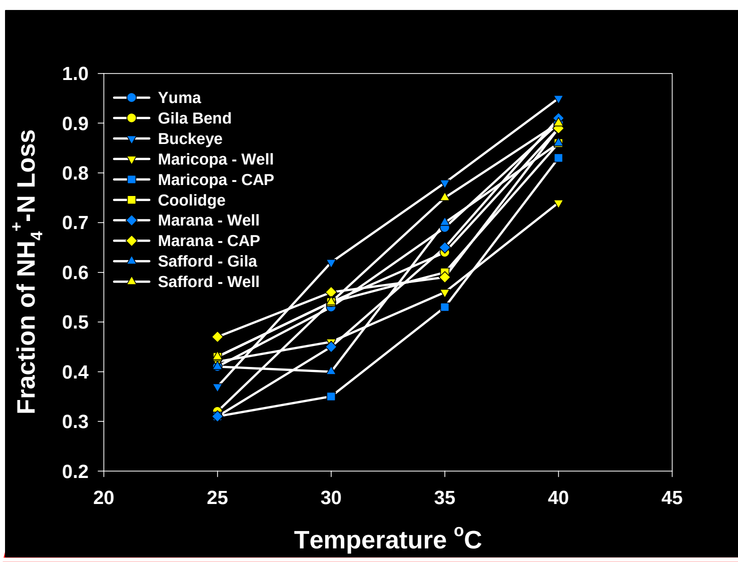
Materials and Methods

- **10 sources of water – different qualities**
- **Added known amount of $(NH_4)_2SO_4$ to beaker of water at constant temperature (25, 30, 35, and 40^{o}C)**
- **300 ml added 10 mg $(NH_4)_2SO_4$**
- **Initial solution: approximately 9 ppm NH_4^+-N**
- **Draw aliquots over time (24 hours)**
- **Analyze for NH_4^+-N**

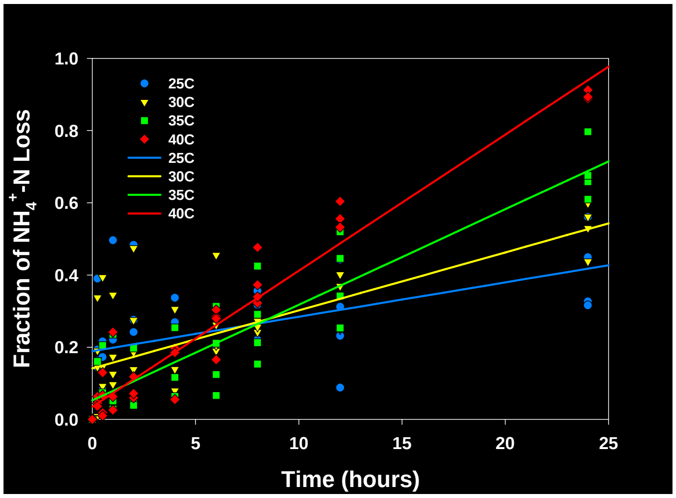
Irrigation Water Quality

Sample	pH	Ca	Mg	Na	K	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^-	NO_3^-	PO_4^{2-}	EC	SAR	SSP	TSS
		--					mg L^{-1}				--	dS	Adj.		ppm
1	8.2	74	33	130	4.8	0	148.8	120	100	0.5	0.03	0.7	6.2	46.4	611
2	8.6	180	56	590	11.6	4.8	151.3	820	160	5.6	0.31	1.9	21.5	64.9	1981
3	8.3	42	29	250	8.7	1.2	185.4	340	48	3.8	0.14	1.0	13.7	69.8	909
4	8.4	220	40	330	4.9	1.2	102.5	420	230	16.4	0.06	1.5	11.1	49.9	1366
5	8.5	69	22	170	4.2	2.4	70.8	160	110	3.2	0.03	0.7	7.2	57.9	612
6	8.6	46	13	61	5.1	8.4	87.8	75	39	0.9	0.25	0.4	3.3	43.1	337
7	8.6	25	6	66	2.2	4.8	109.8	41	22	4.0	0.02	0.5	4.3	61.4	281
8	8.1	60	33	100	4.9	0	90.3	93	93	0.2	0.02	0.5	4.4	42.7	475
9	8.4	40	12	110	7.1	2.4	131.8	150	17	0.8	0.09	0.5	6.4	60.2	471
10	8.3	41	13	380	3.3	1.2	302.6	300	78	5.5	0.04	1.3	25.3	83.8	1125

Total Fractional Loss of N= f(T)



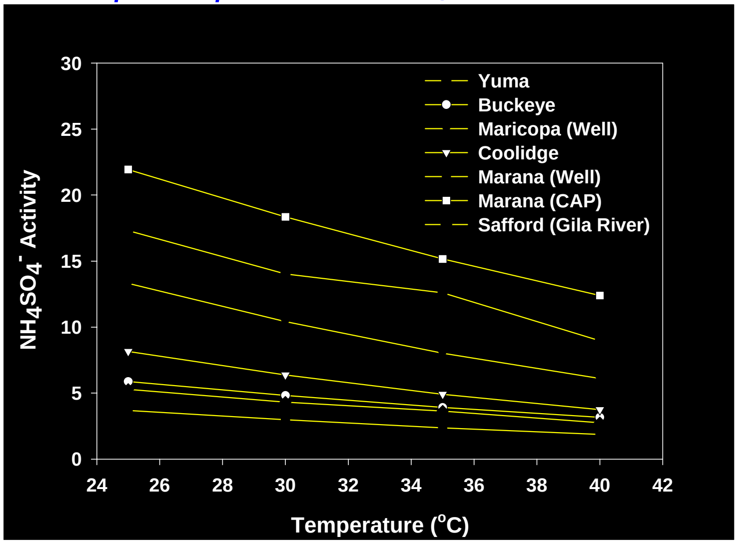
Yuma Valley - Colorado River Water



Results – N Volatilization

- **Effect of temperature was greater in waters with lower total soluble salts**
  - **Specifically SO_4^{-2}-S**

$NH_4SO_4^-$ Activity



Multivariate Linear Regression Analysis

- **Decreased fractional loss with increased concentrations of SO_4^{-2}-S**
  - **Application of Le Chatelier's principle**
    - **Common Ion Effect**
    - **Predicts that a salt will be less soluble if one of its constituent ions is present in solution**

$$(NH_4)_2SO_{4(s)} \Leftrightarrow 2NH_4^+ + SO_4^{2-}$$

$$NH_4^+ + OH^- \Leftrightarrow NH_{3(g)} + H_2O$$

Conclusions

- **Potential for loss is present**
  - **Temperatures of 30 – 35 °C may lose up to 30% in first 10 hours**
  - **Up to 50% at higher temperatures**
- **Form of fertilizer (ammoniacal)**
  - **NH_3 may be greater**
  - **UAN 32 may be less**
- **In general higher soluble salts (EC_w) increase potential for loss**
  - **Exception – SO_4^{2-}-S**

Summary – Fertigation of Arid and Saline Soils

- **Opportunities – improved efficiency**
- **Salinity/Na management**
- **Water Quality interactions**
  - **Precipitation reactions**
  - **Volatilization (N)**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