Cotton Crop Water Use

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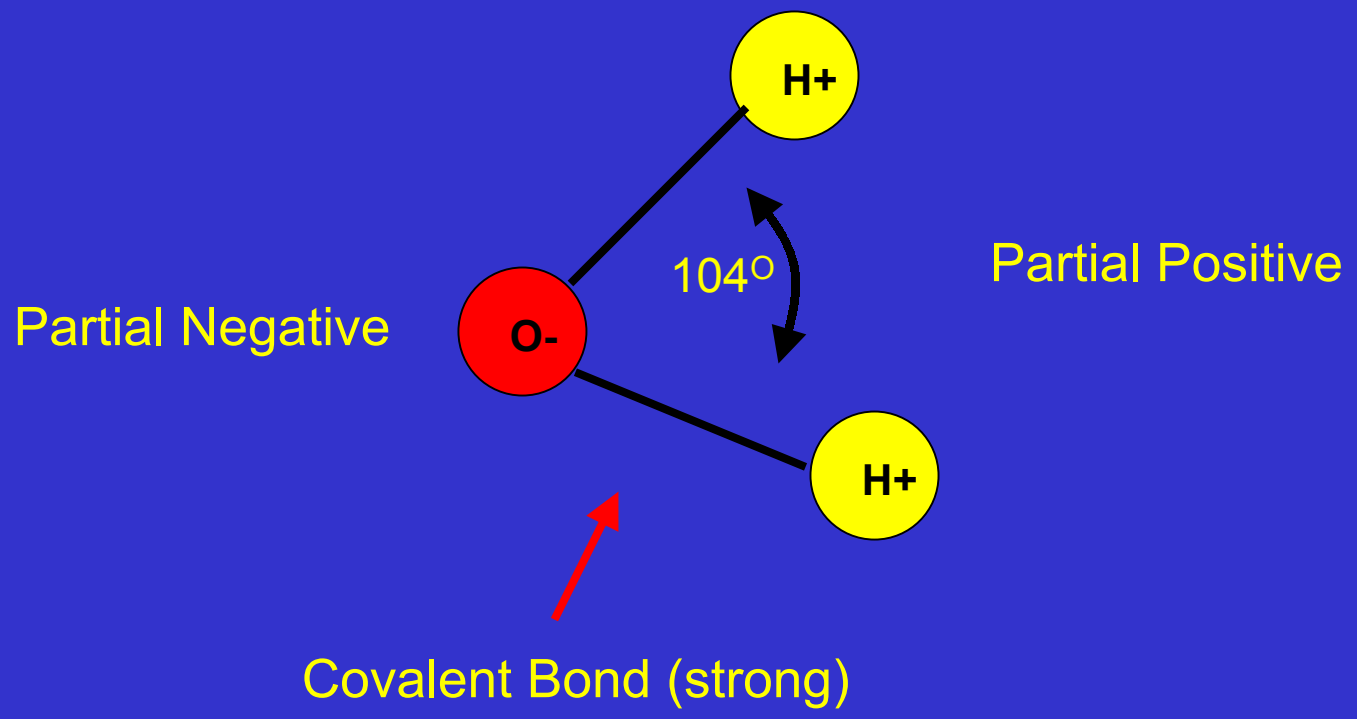
Topics Covered in This Discussion

- Properties of water.
- Functions of water in the plant.
- How does water move in the plant?
- Crop water use.
- Irrigation scheduling.

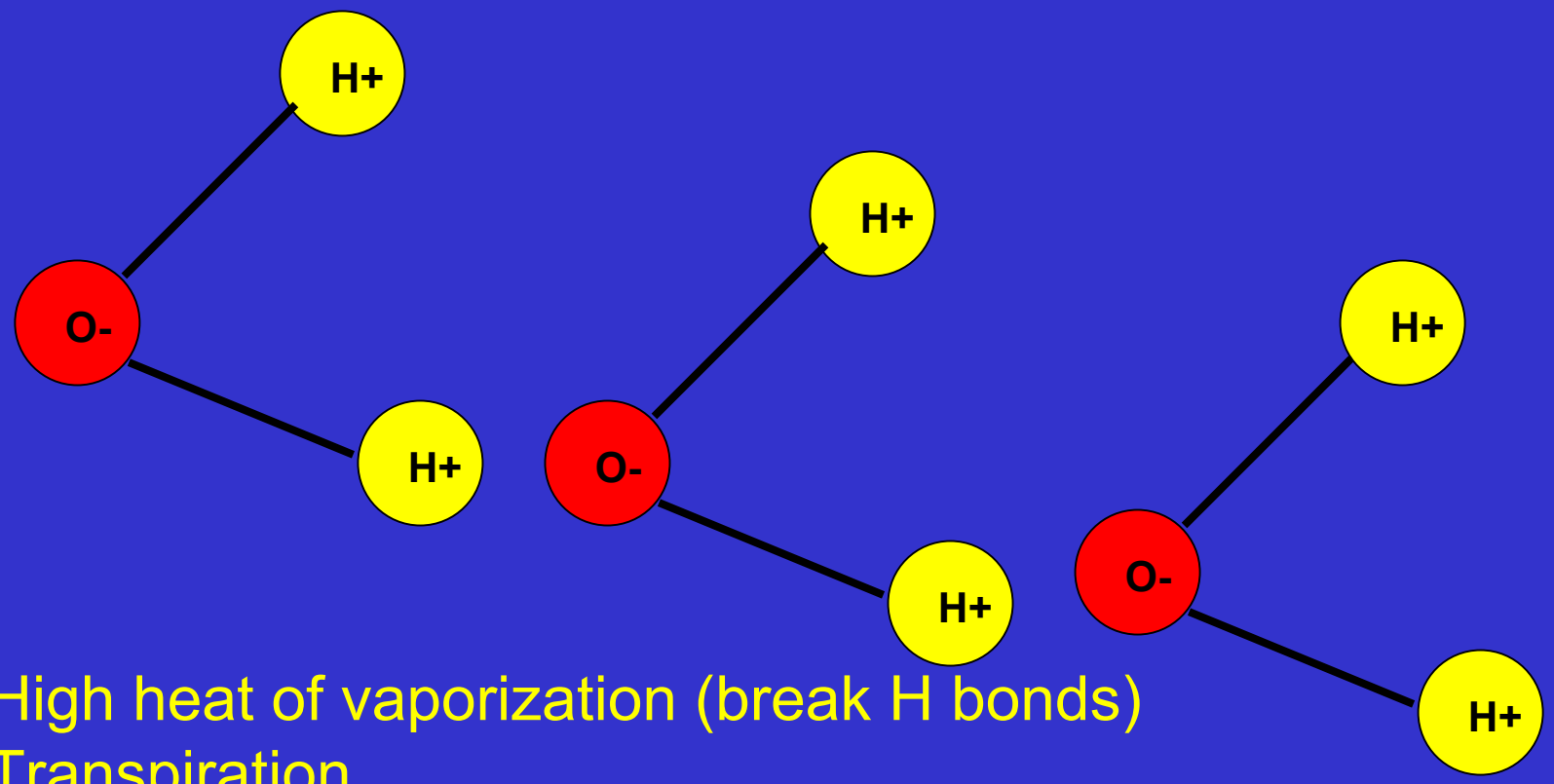
PROPERTIES OF WATER (H_20)
polar molecule



WATER SPLIT IN LIGHT RXNS

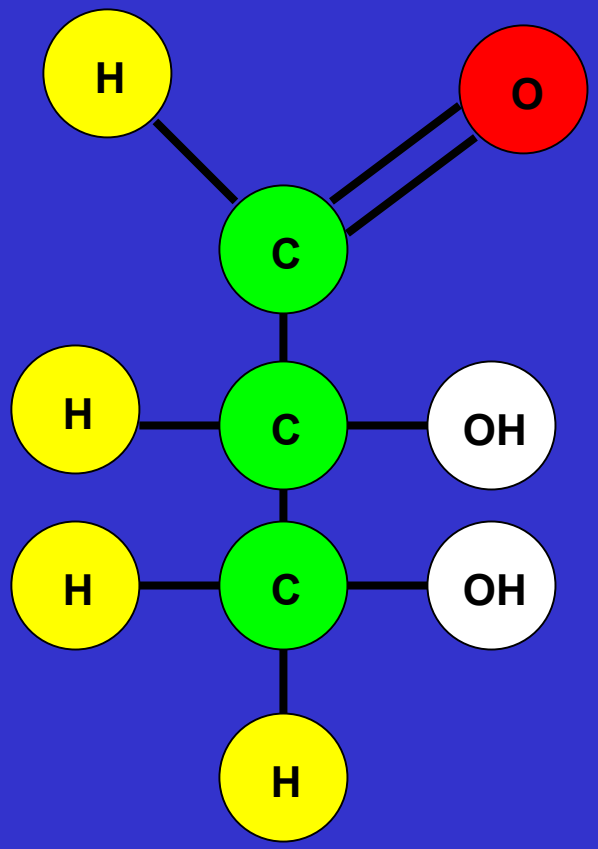
COTTON ABSORBANT

HYDROGEN BONDING

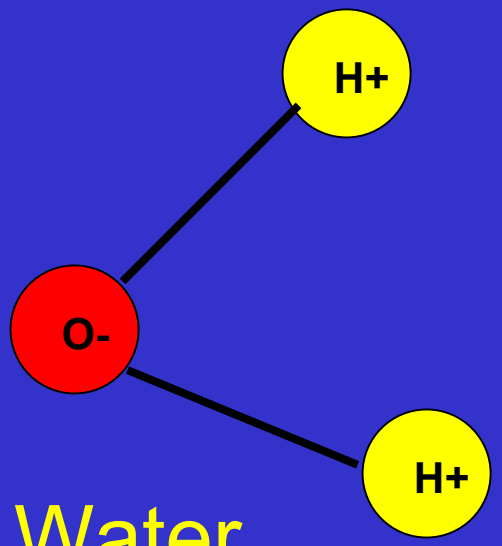


High heat of vaporization (break H bonds)
Transpiration
High heat of fusion (freezing)
Most dense at 4 degrees C (kinetic E, lattice)
Expands upon freezing (floats, pipes, antifreeze)
Other molecules with similar mole weights

HYDROGEN BONDING (SOLVENT)

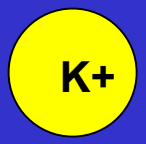


Carbohydrates



Water

Salts (ionize)



Minerals

FUNCTIONS OF WATER (H_20)

- Constituent – 80-90% of fresh weight.
- Solvent – minerals, CHO's, other solutes.
  Solutes must be dissolved for transport.
- Reactant – Photosynthesis (split water, Hill).
- Turgidity – Cell growth, fiber elongation.
- Coolant – Transpiration.

HOW DOES WATER MOVE?

Xylem and Phloem: The infrastructure of long distance transport.

X – inside

P – outside (girdle)

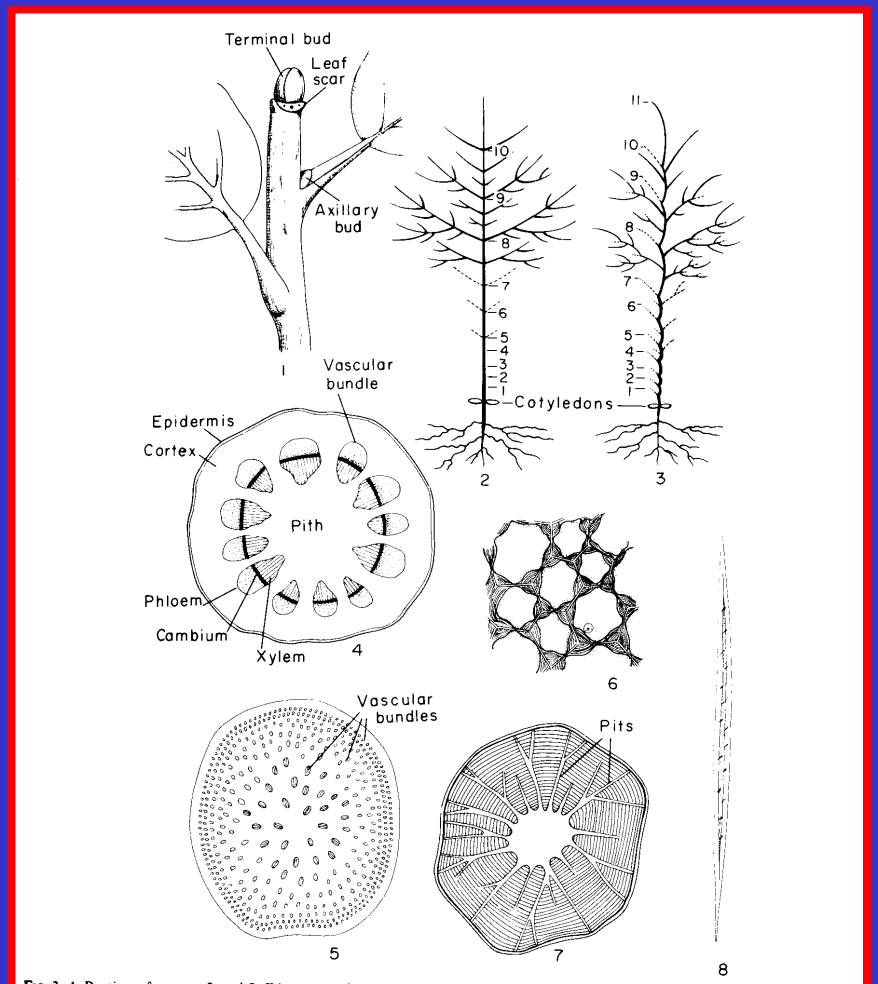


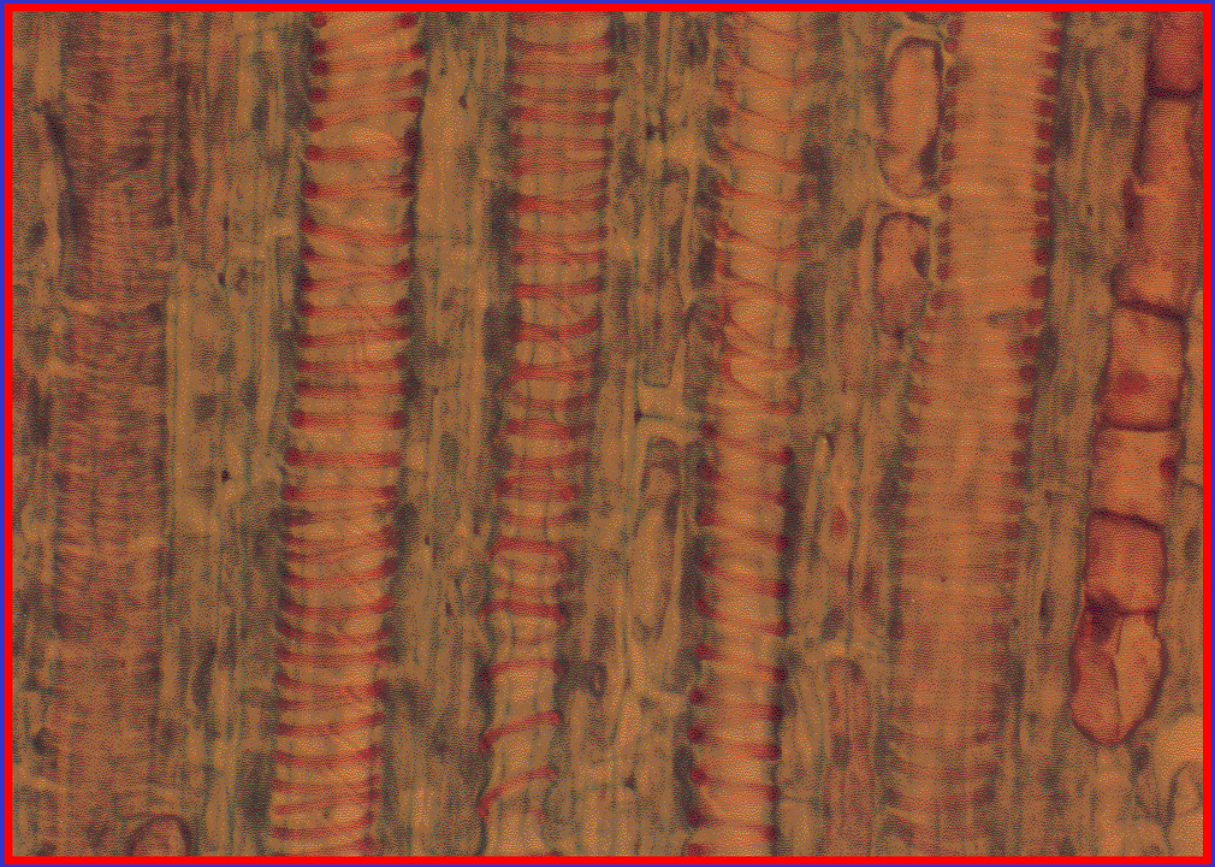
FIG. 3. 1, Portion of a stem. 2 and 3, Diagrams of monopodial and sympodial branching respectively (the numbers indicate the position of the tip at the end of each annual longitudinal increment). 4, Diagram of a cross-section of a young dicotyledonous stem. 5, Diagram of a cross-section of a monocotyledonous stem. 6, Cross-section of collenchyma. 7, An isodiametral sclereid. 8, A fibre. (Nos. 2 and 3 adapted from Troll, 1948.)

HOW DOES WATER MOVE?
Xylem

Transport water and minerals from soil to shoot.

TENSION – CAVITATION

Cells are dead with no organelles or membrane (soda straw).



HOW DOES WATER MOVE?
Phloem

Transport CHO's from shoot to root.

PRESSURE

Cells are living with organelles and membrane (CHO loading and unloading.)

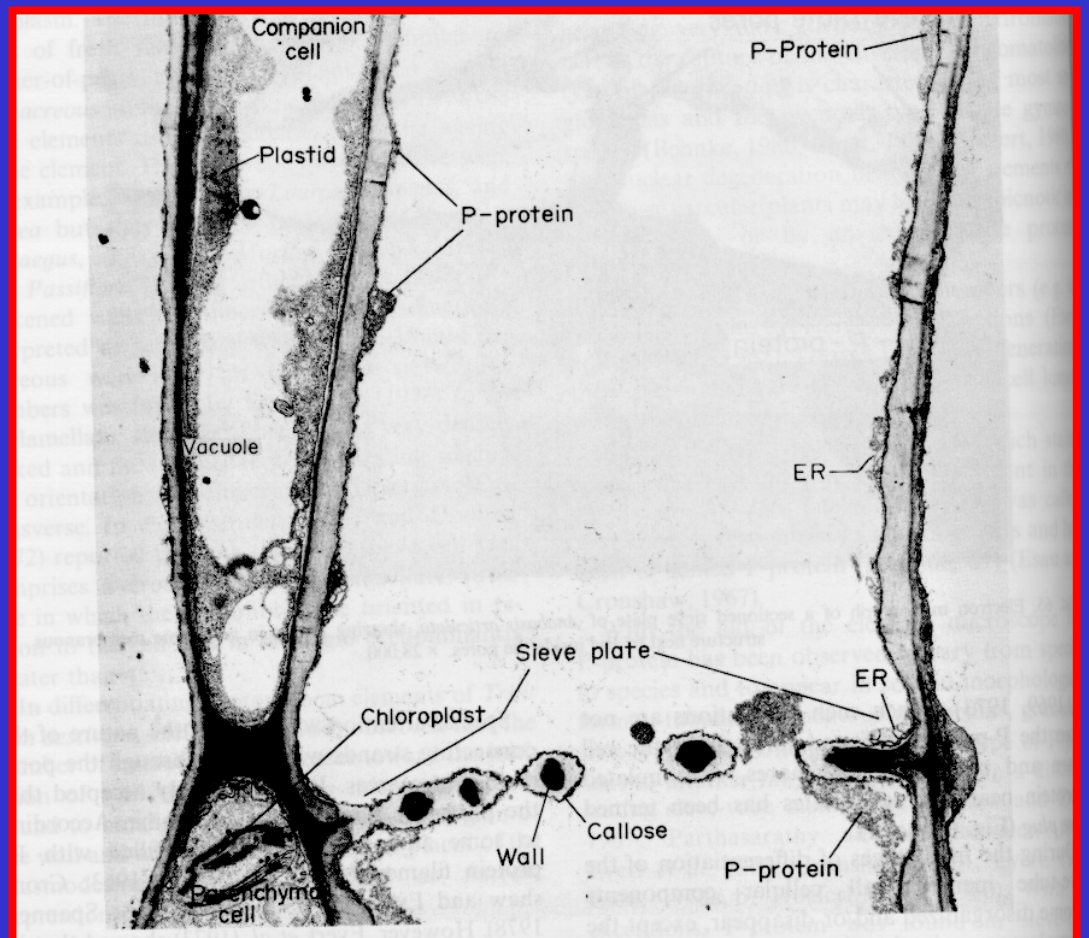


FIG. 66. Electron micrograph of a longitudinal section of *Cucurbita maxima* sieve-tube members, showing sieve plate Companion cells on left, above × 10,000. (Courtesy of R. F. Evert.)

HOW DOES WATER MOVE?

Status of Free Energy (water potential)

$$\psi_w = \psi_s + \psi_p + \psi_m + \psi_g$$

ψ_s = solute potential (osmotic adjustment)

ψ_p = pressure potential

ψ_m = matric potential

ψ_g = gravitational potential (0.01 MPa/m)

HOW DOES WATER MOVE?

How Does Free E Affect?

Mass Flow: Long Distance

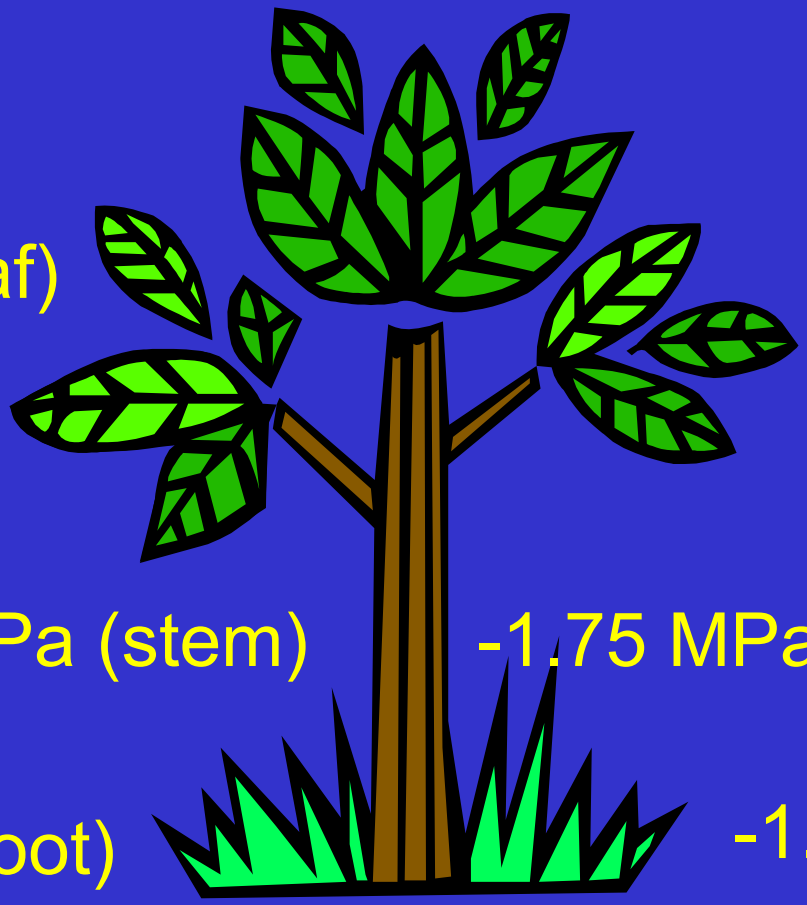
Move in mass in response to force SA pressure or gravity.

Diffusion: Local

Random movement caused by own kinetic E.

Osmosis: Cellular

Diffusion across membrane.



-1.0 MPa (leaf)

-2.0 MPa (leaf)

-1.0 MPa (stem)

-1.75 MPa (stem, cavitate)

-1.0 MPa (root)

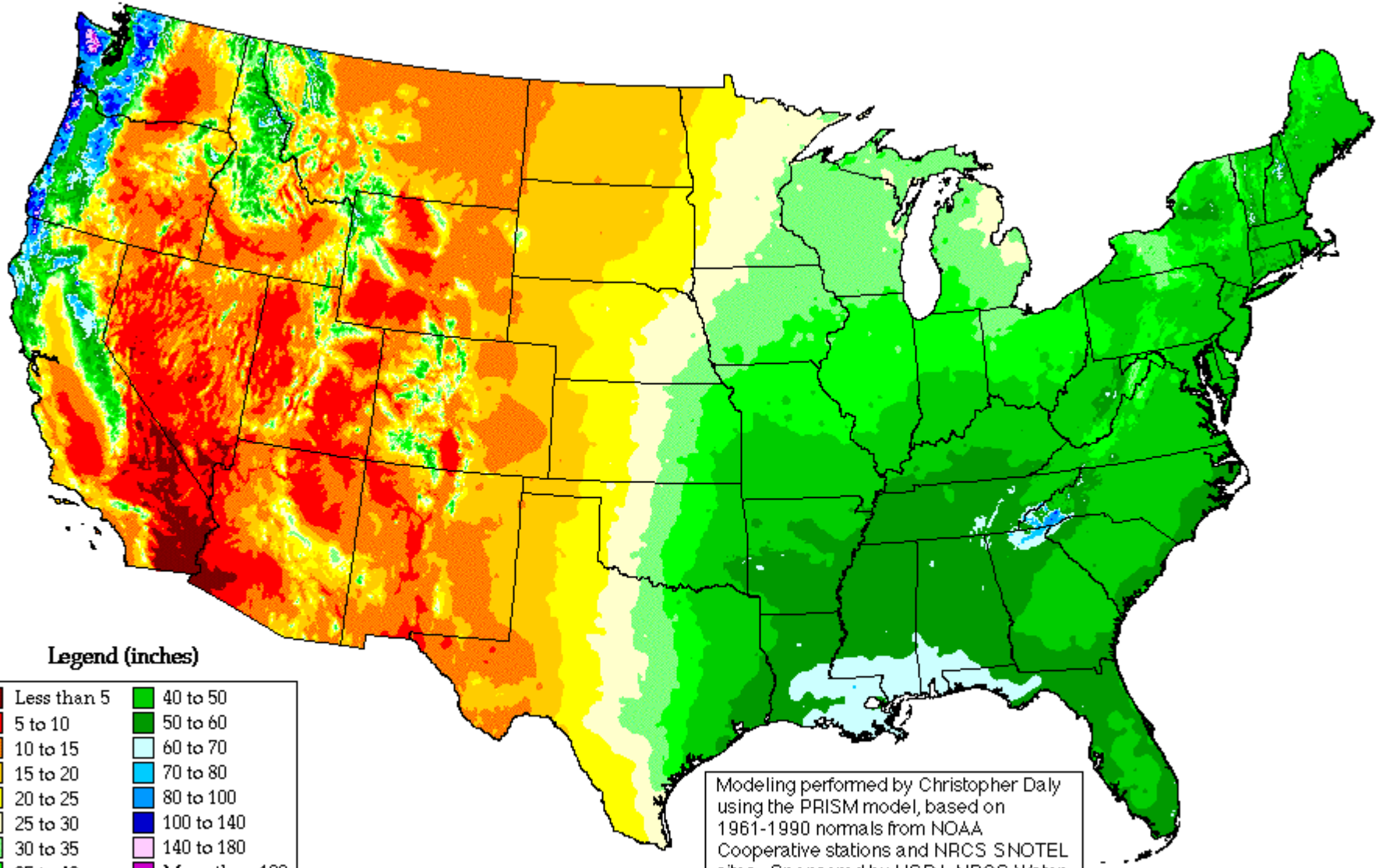
-1.5 MPa (root)

-1.0 MPa (soil)

-1.0 MPa (soil)

Annual Average Precipitation

United States of America



Legend (inches)

Less than 5	40 to 50
5 to 10	50 to 60
10 to 15	60 to 70
15 to 20	70 to 80
20 to 25	80 to 100
25 to 30	100 to 140
30 to 35	140 to 180
35 to 40	More than 180

Period: 1961-1990

Modeling performed by Christopher Daly using the PRISM model, based on 1961-1990 normals from NOAA Cooperative stations and NRCS SNOTEL sites. Sponsored by USDA-NRCS Water and Climate Center, Portland, Oregon.

Oregon Climate Service
George Taylor, State Climatologist
(541) 737-5705

WHY ARE WE SO INTERESTED IN COTTON CROP WATER USE?

WHY MUST WE IRRIGATE?

A COTTON CROP REQUIRES 18 INCHES OF WATER.

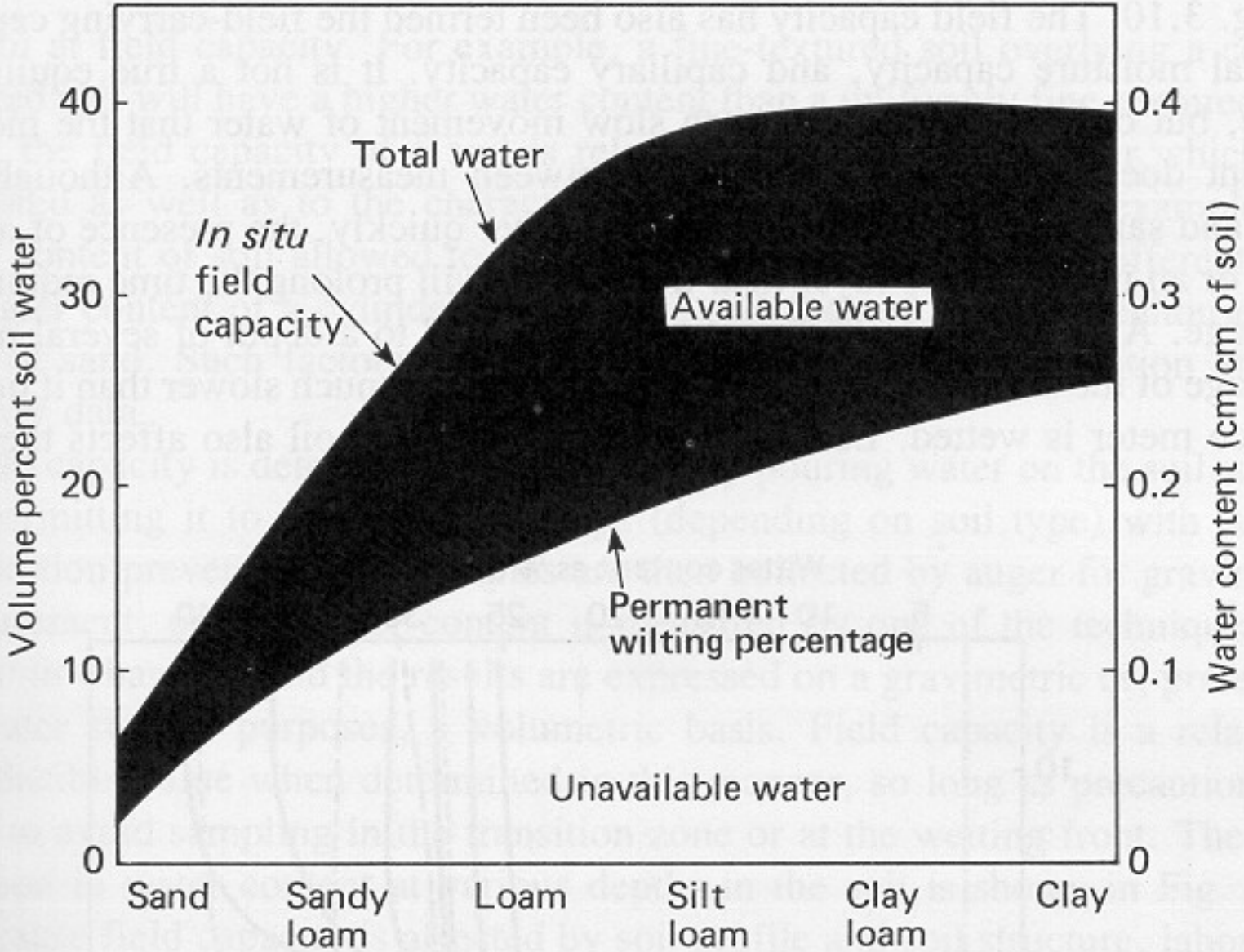


Fig. 3.9. Diagram showing the relative amounts of available and unavailable water in soils ranging from sand to clay. Amounts are expressed as percentages of soil volume and as centimeters of water per centimeter of soil. (From Cassell, 1983.)

Tifton Soil Series

Most extensive soil in the state (27% of state farmland).

Cotton and peanuts grown extensively on these soils.

Loamy Sand

Within a rooting depth of 40” will hold 2.75” of water.

“We are about one week away from a drought at any time during the growing season.”

EVAPOTRANSPIRATION (ET)

ET the sum of water losses due to soil-water evaporation (E) and crop water transpiration (T):

$$ET = E + T$$

Heat of Vaporization of Water = 2.43 MJ/kg

Incident Radiation During Summer = 25 MJ/day

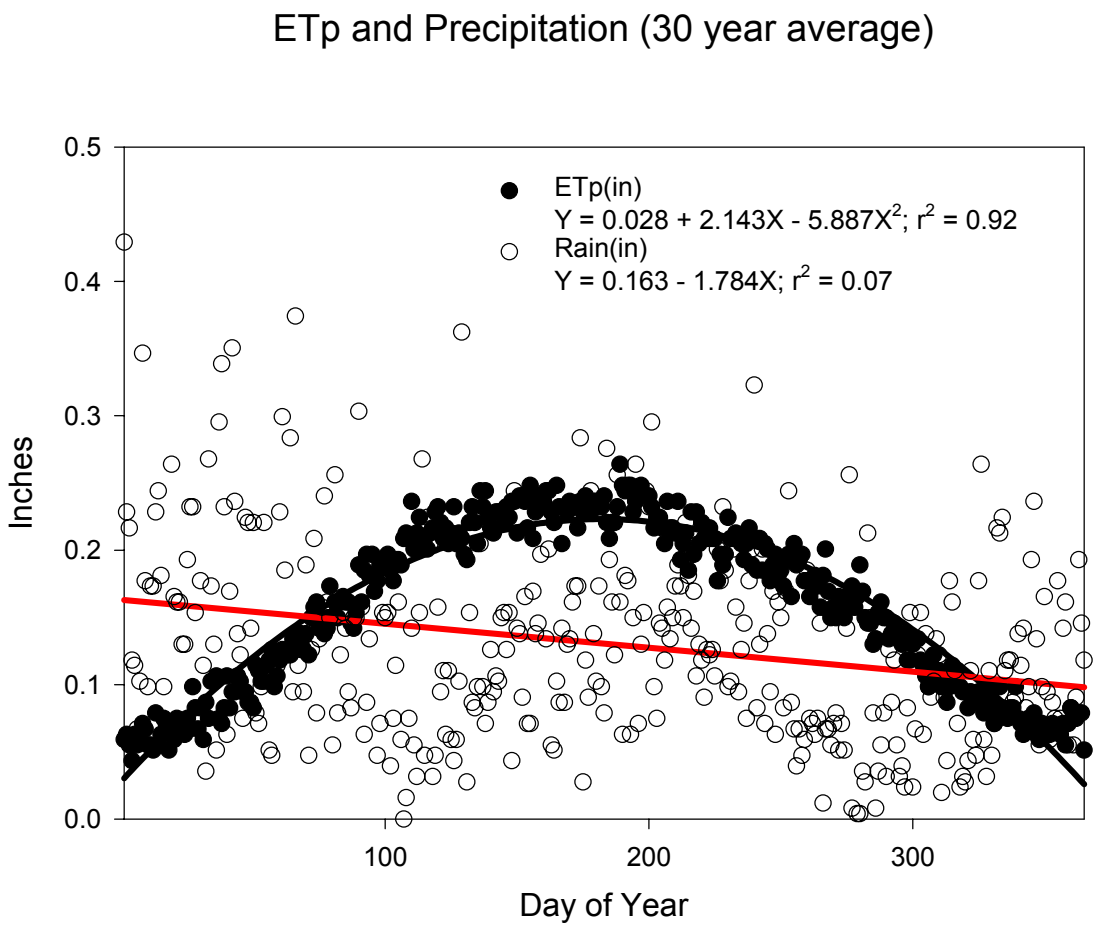
If all absorbed would evaporate 0.4” water

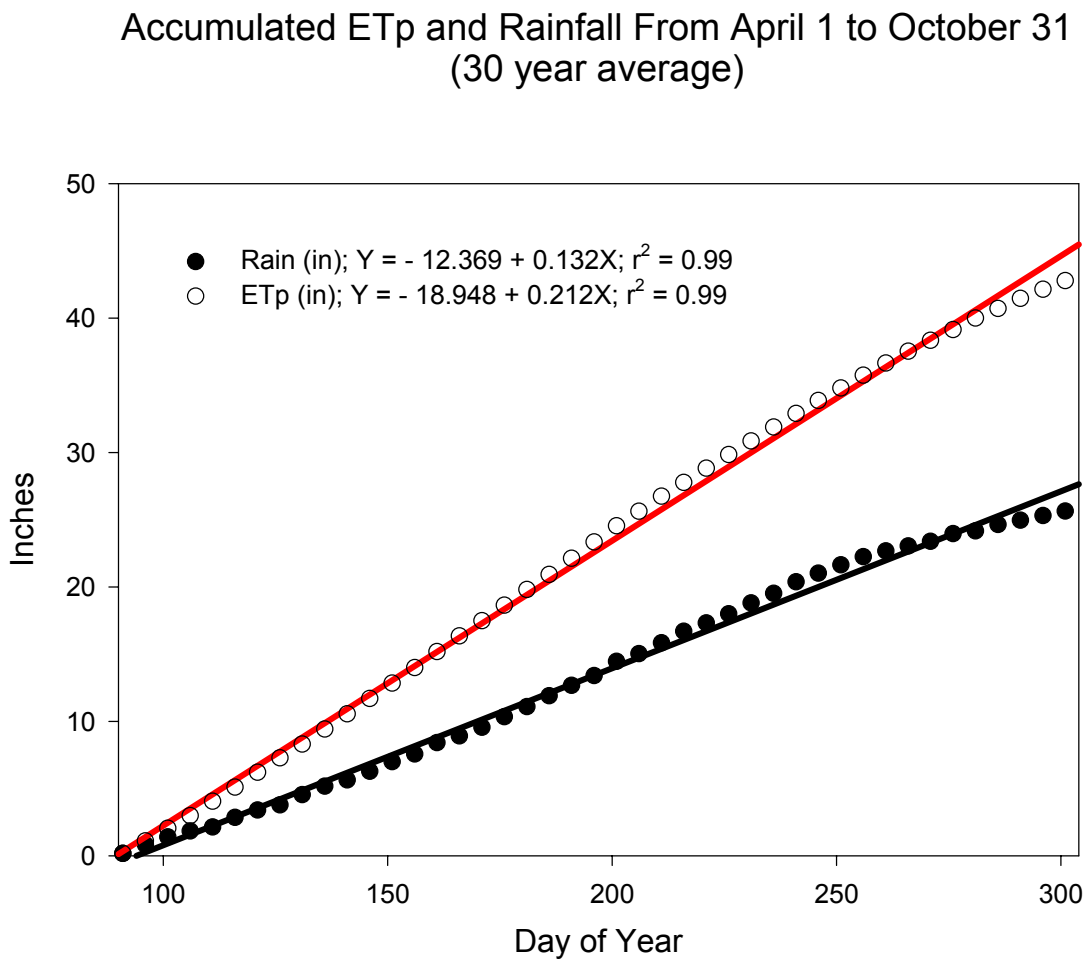
POTENTIAL EVAPOTRANSPIRATION (ETp)

ETp – the potential amount of water lost by ET during the day.

INFLUENCED BY:

- **Wind speed**
- **Air temperature**
- **Air humidity**
- **Solar radiation**
- **Rainfall**


ETp and Precipitation (30 year average)
ETp(in)
Y = 0.028 + 2.143X - 5.887X2; r2 = 0.92
Rain(in)
Y = 0.163 - 1.784X; r2 = 0.07
Inches
0.0
0.1
0.2
0.3
0.4
0.5
100
200
300
Day of Year

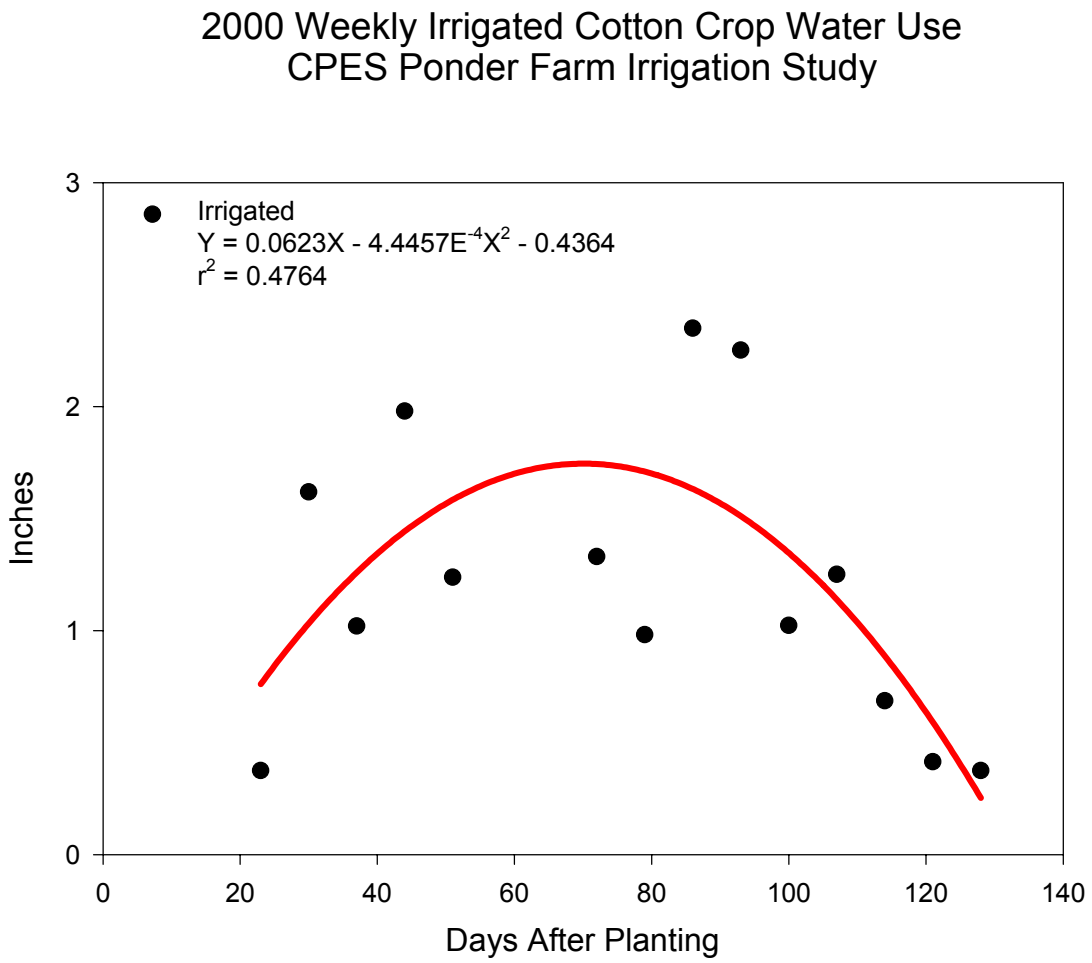

Accumulated ETp and Rainfall From April 1 to October 31
(30 year average)
Rain (in); Y = - 12.369 + 0.132X; r2 = 0.99
ETp (in); Y = - 18.948 + 0.212X; r2 = 0.99
Inches
Day of Year
0
10
20
30
40
50
100
150
200
250
300

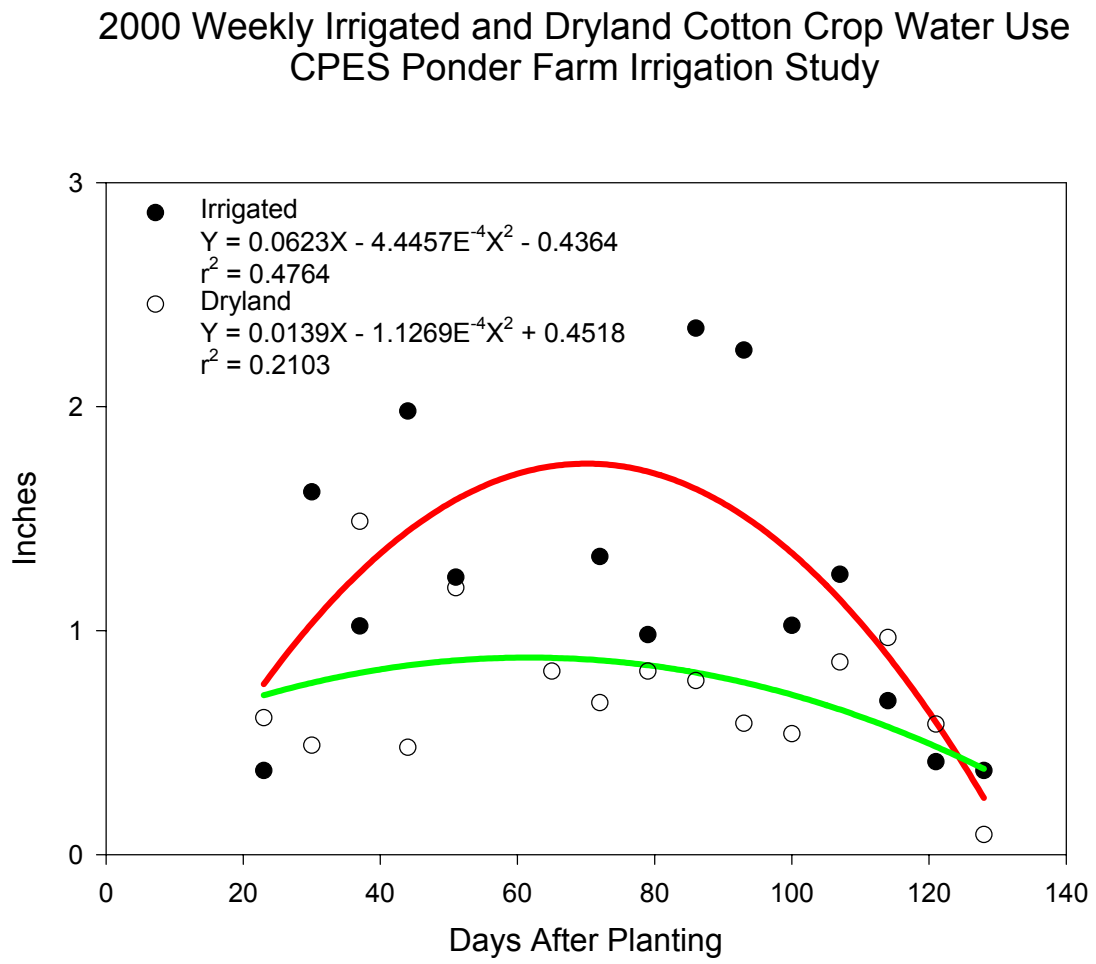
WHY ARE WE SO INTERESTED IN COTTON CROP WATER USE?

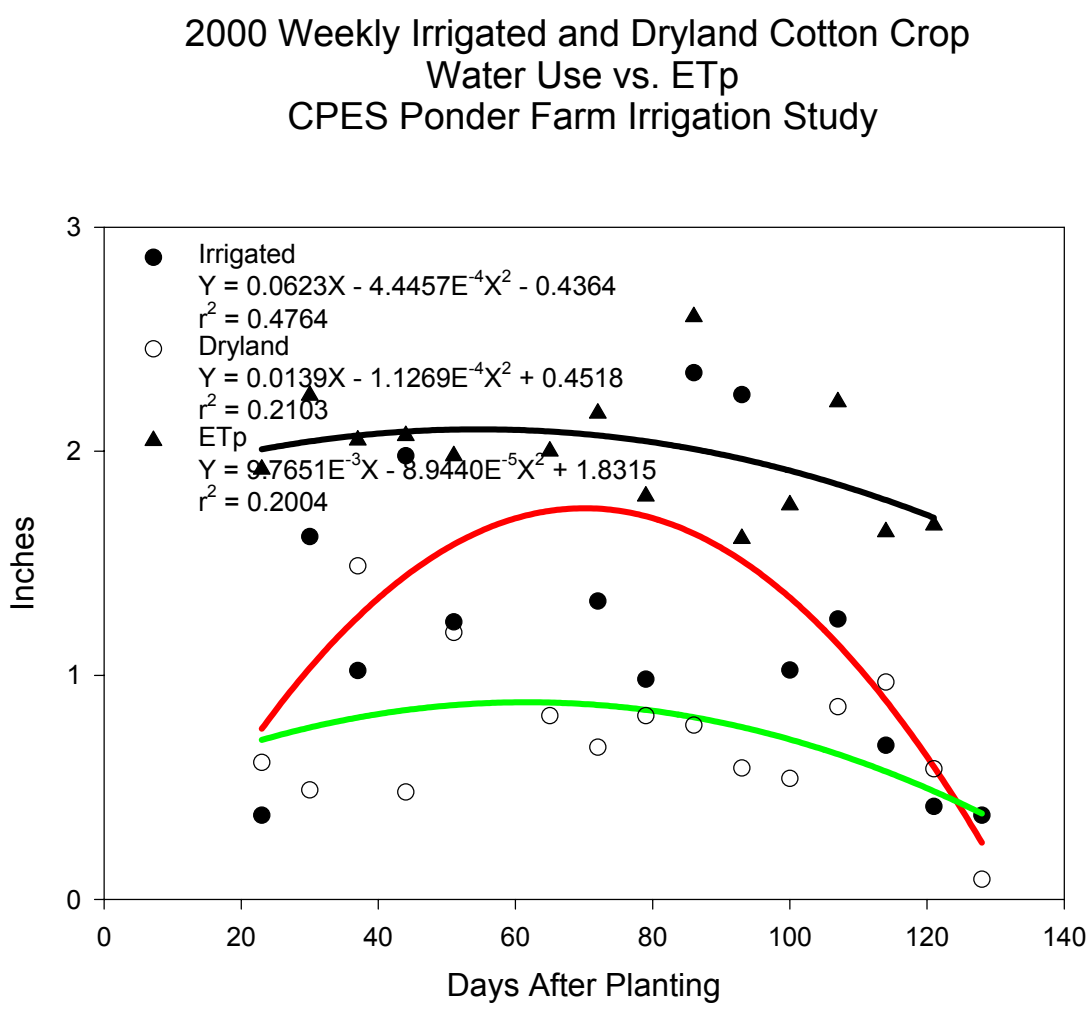
- SOIL WATER HOLDING CAPACITY (Depth and Texture)
- RAINFALL DISTRIBUTION PATTERNS

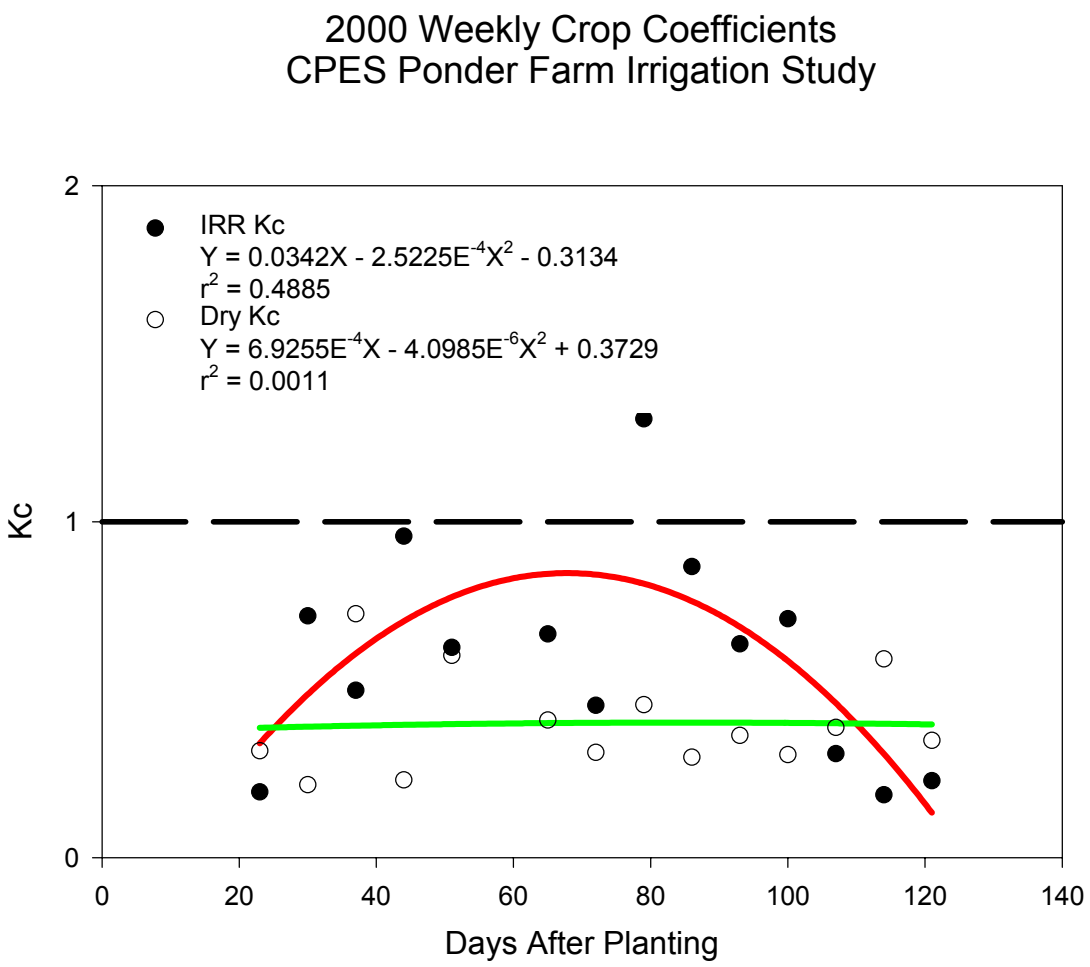
ETp VS. ACTUAL EVAPOTRANSPIRATION (ETa)

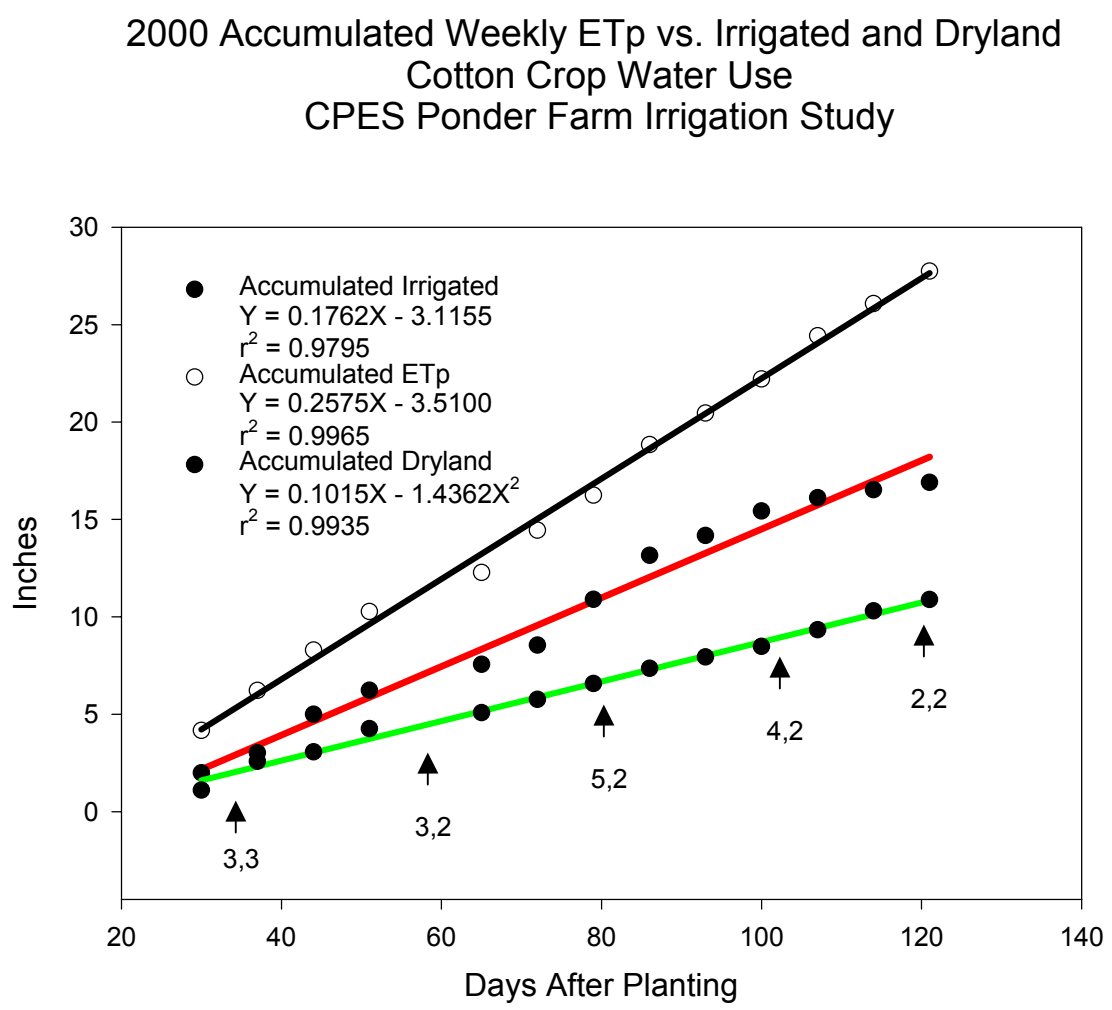
- **ETp IS FREE EVAOPRATION**
- **SOIL AND PLANT RESISTANCES TO ET**
- **ETa ACCOUNTS FOR THESE RESISTANCES**
- **ETp X Kc = CROP WATER USE (ETa)**
- **Kc = RATIO OF ETa TO ETp**


2000 Weekly Irrigated Cotton Crop Water Use
CPES Ponder Farm Irrigation Study
Irrigated
Y = 0.0623X - 4.4457E-4X2 - 0.4364
r2 = 0.4764
Inches
Days After Planting
0
1
2
3
0
20
40
60
80
100
120
140


2000 Weekly Irrigated and Dryland Cotton Crop Water Use
CPES Ponder Farm Irrigation Study
Irrigated
Y = 0.0623X - 4.4457E-4X2 - 0.4364
r2 = 0.4764
Dryland
Y = 0.0139X - 1.1269E-4X2 + 0.4518
r2 = 0.2103
Inches
Days After Planting
0
1
2
3
0
20
40
60
80
100
120
140


2000 Weekly Irrigated and Dryland Cotton Crop
Water Use vs. ETp
CPES Ponder Farm Irrigation Study
Irrigated
Y = 0.0623X - 4.4457E-4X2 - 0.4364
r2 = 0.4764
Dryland
Y = 0.0139X - 1.1269E-4X2 + 0.4518
r2 = 0.2103
ETp
Y = 9.7651E-3X - 8.9440E-5X2 + 1.8315
r2 = 0.2004
Inches
Days After Planting
0
1
2
3
0
20
40
60
80
100
120
140


2000 Weekly Crop Coefficients
CPES Ponder Farm Irrigation Study
IRR Kc
Y = 0.0342X - 2.5225E-4X2 - 0.3134
r2 = 0.4885
Dry Kc
Y = 6.9255E-4X - 4.0985E-6X2 + 0.3729
r2 = 0.0011
Kc
2
1
0
0
20
40
60
80
100
120
140
Days After Planting


2000 Accumulated Weekly ETp vs. Irrigated and Dryland
Cotton Crop Water Use
CPES Ponder Farm Irrigation Study
Accumulated Irrigated
Y = 0.1762X - 3.1155
r2 = 0.9795
Accumulated ETp
Y = 0.2575X - 3.5100
r2 = 0.9965
Accumulated Dryland
Y = 0.1015X - 1.4362X2
r2 = 0.9935
3,3
3,2
5,2
4,2
2,2
Inches
Days After Planting
30
25
20
15
10
5
0
20
40
60
80
100
120
140

ONE GOAL OF OUR RESEARCH IS TO DEVELOP A SET OF WEEKLY Kc UNDER GEORGIA GROWING CONDITIONS.

- **ETp from weather station, internet, county extension office, etc.**
- **Kc from UGA research**

ADJUSTING FOR IRRIGATION SYSTEM EFFICIENCY

- **ETp X Kc / EFF = IRRIGATION WATER REQUIREMENT**
- **APPLICATION EFFICIENCY**
- **DISTRIBUTION EFFICIENCY**
- **IRRIGATION GUN = 50%**
- **CENTER PIVOT = 55 – 80%**

TYPES OF EFFICIENCY
Can We Improve It?

- **PLANT WATER USE EFFICIENCY?**
  - **Unit Lint Yield/Unit Water Used**
    - **Genetically Determined**
    - **Modern Cultivars Less Efficient**
- **APPLICATION EFFICIENCY?**
  - **Unit Water Available/Unit Water Applied**
- **MANAGEMENT EFFICIENCY?**
  - **Timing of Water Applications**

TYPES OF EFFICIENCY
Can We Improve It?

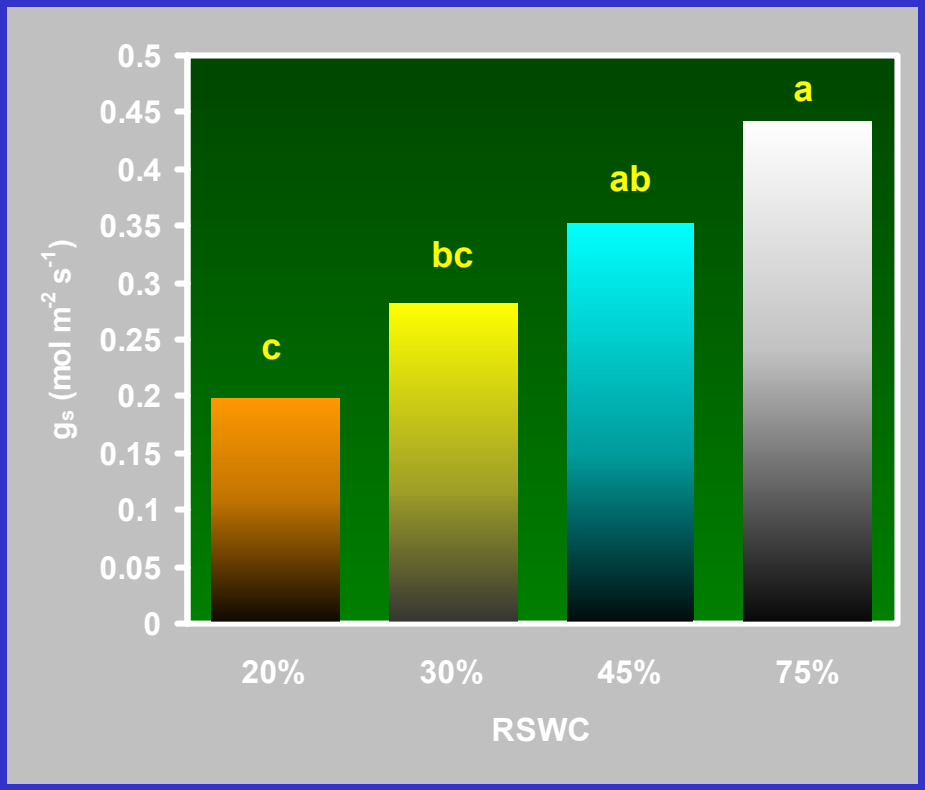
PLANT WATER USE EFFICIENCY?

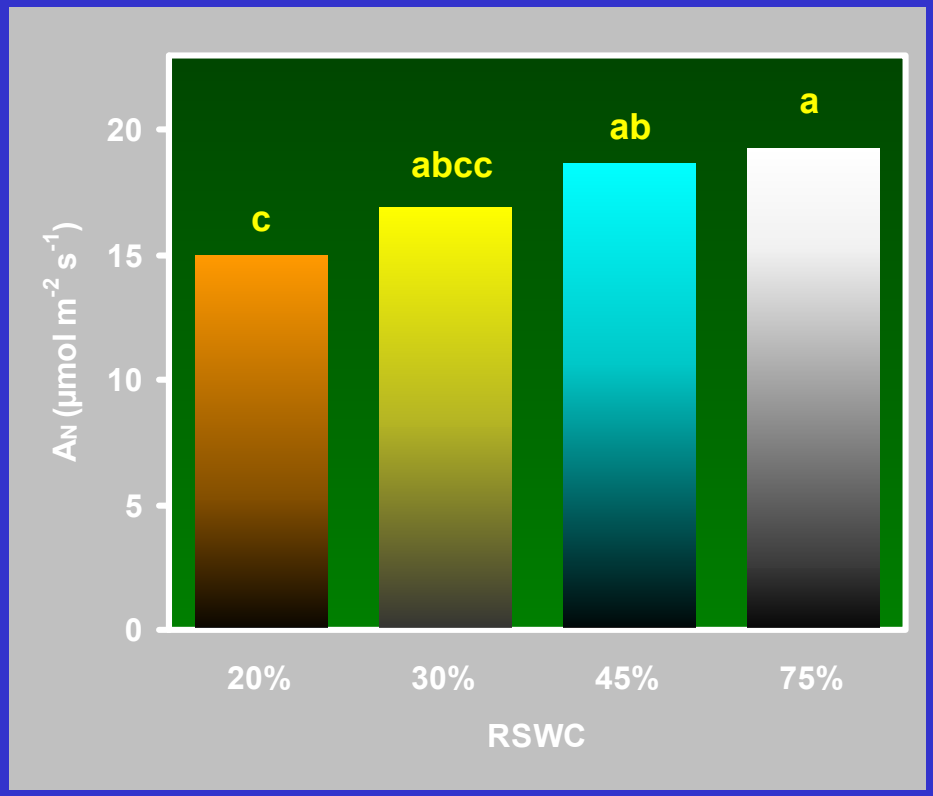
DRY: 845 lbs / 10.976” = 76.99
IRR: 1191 lbs / 17.898” = 66.54

MANAGEMENT EFFICIENCY (TIMING)

- **INSECTICIDE APPLICATIONS BASED ON INSECT PRESSURE AND IDENTIFICATION**
- **HERBICIDE APPLICATIONS BASED ON WEED PRESSURE AND IDENTIFICATION**
- **FERTILITY**
- **WHAT DO WE BASE IRRIGATION SCHEDULING ON?**
  - **Visual Symptoms**
  - **When and How Much Water Do We apply?**
  - **Determine Weekly Crop Water Use.**

When do plants sense a water deficit?

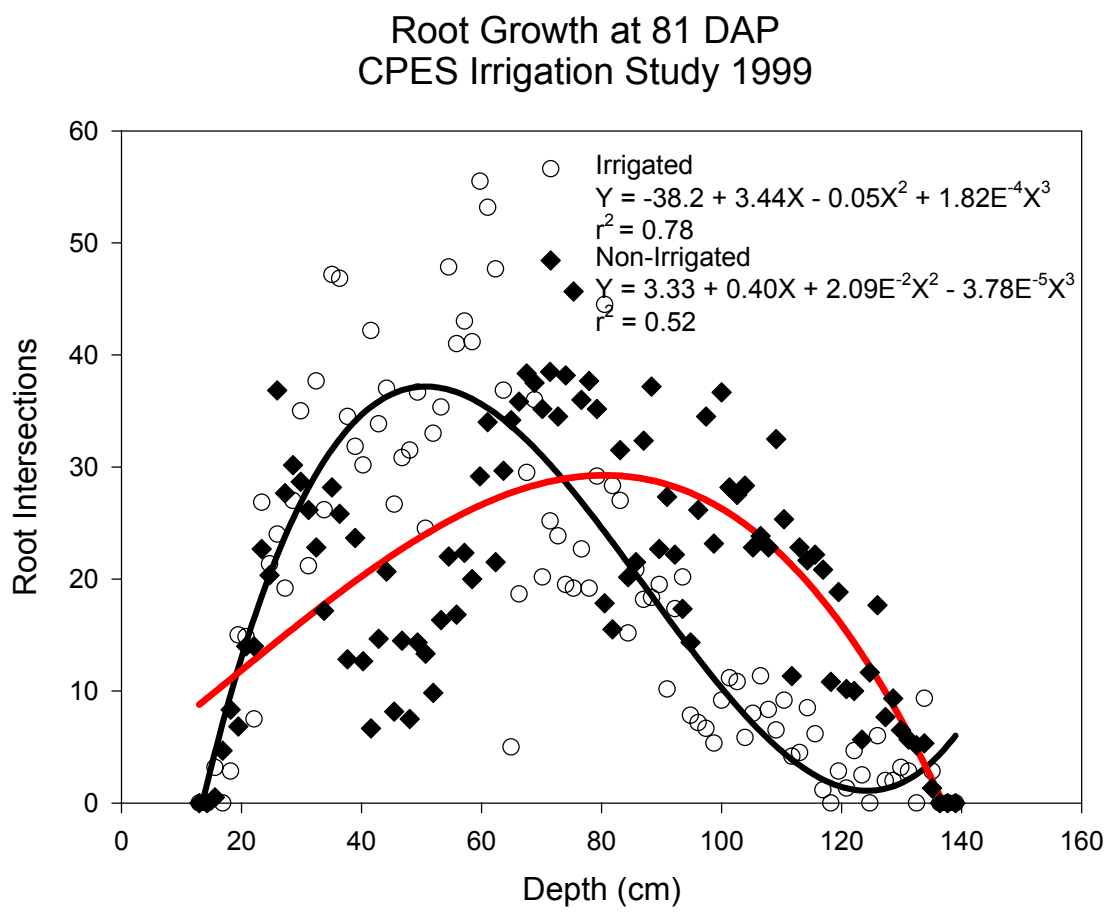




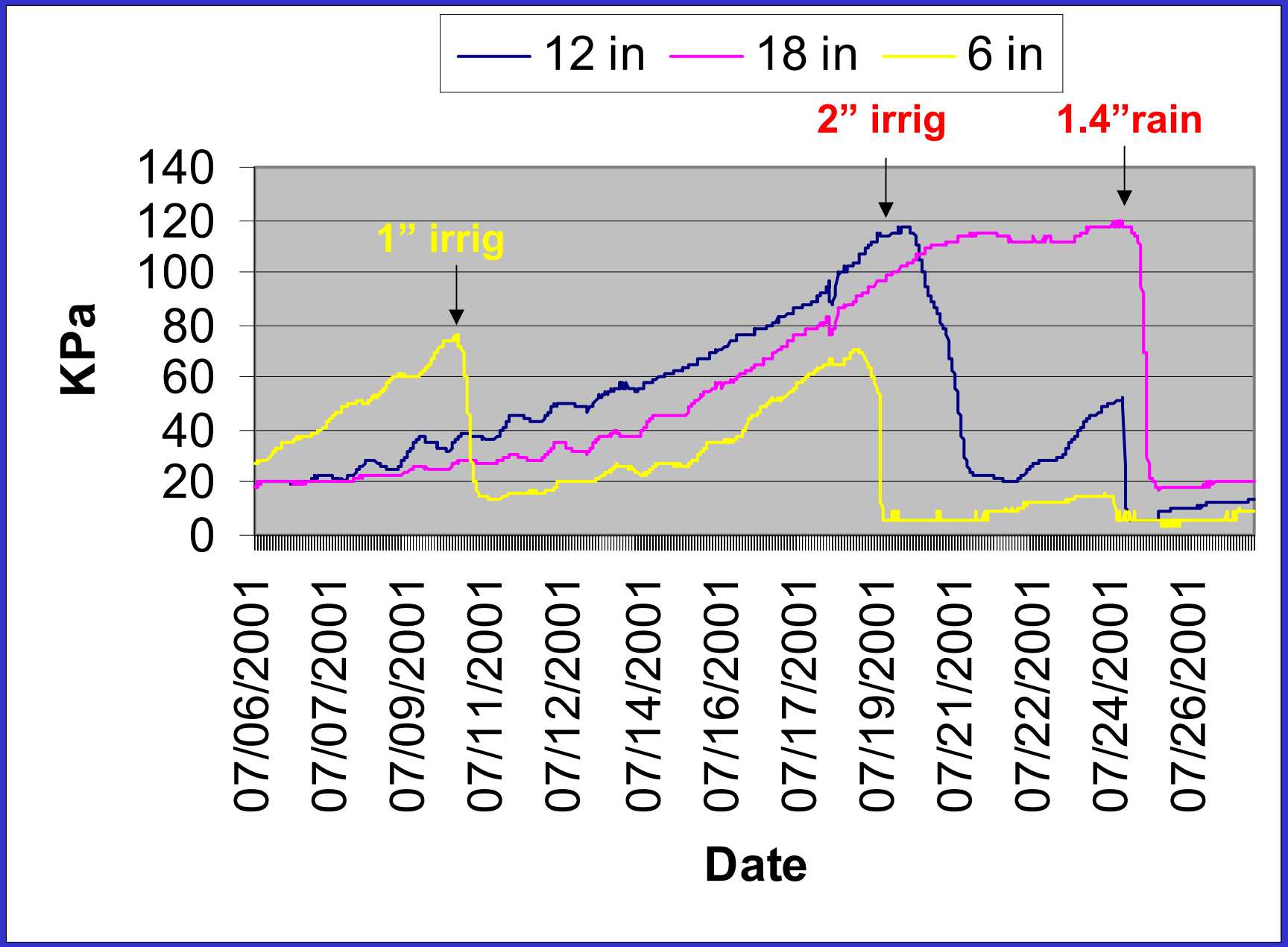
Assume 3 mmol m^{-2} s^{-1} reduction for 12 h day. Assume plants are 40% C = 35 lbs ac^{-1} d^{-1} loss in total biomass.

Source: H.J. Earl
Univ. of GA, Athens

TIMING EXAMPLE



Gibbs Farm 2001



TIMING EXAMPLE

Table 2. Supplying water to cotton at specific stages of development affects its subsequent yield as well as the components of that yield. The higher the number in the table, the more closely correlated the factors are.

	Lint Yield m^{-2}	Boll m^{-2}	Boll $plant^{-1}$	Lint $boll^{-1}$	Lint $plant^{-1}$
Total Water Supply	0.34	0.35	0.37	0.12	0.36
WS P SI	-0.32	-0.18	-0.08	-0.24	-0.22
WS SI FF	0.73	0.58	0.54	0.65	0.68
WS FF- PB	0.32	0.55	0.23	0.04	0.13
WS PB- Maturity	-0.43	-0.45	-0.23	-0.56	-0.27

WS - Water Supply P- Planting SI - Square Initiation FF - First Flower

PB - Peak Bloom

Source: D.R. Krieg

WHEN DO MOST OF US BEGIN IRRIGATING?

- **By that time our soil water is becoming depleted and we are close to first flower.**
- **Can we be more timely?**
- **In 2000 our crop used 6” in first 60 days.**
- **Water use increases dramatically after that.**
- **Don’t want our soil water to be close to depletion as crop approaches first flower.**