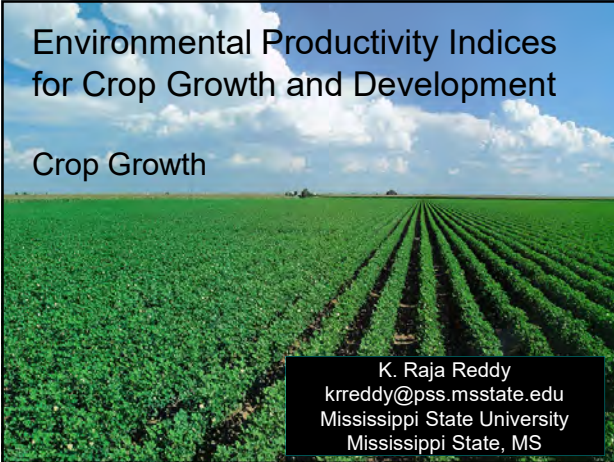


Environmental Productivity Indices for Crop Growth and Development

Crop Growth



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Crop Growth and Development and Environment

Goals and Learning Objectives:

- To understand the effects of multiple environmental factors on crop growth and development.
 - Crop growth and development and environment and applying Environmental Productivity Index (EPI) concept using cotton as an example crop.
 - Crop growth and development and environment: Species variability, and applicability of EPI concept across species.

Crop growth and Development and Environment

You will learn:


- ✓ Effects of environmental factors on crop growth-phenology and growth of various individual organs and/or a plant as a whole.
- ✓ How to develop or build a whole plant or canopy from organ-based functional algorithms.
- ✓ How to calculate potential growth and developmental rates under optimum conditions.
- ✓ How to develop environmental productivity indices for various environmental factors to decrement the potential crop growth rates under multiple environmental conditions.

Terminology and Definitions

- Growth:
 - Growth is an increase in length, area, or weight of plants as a whole or of individual organs.
- Phenology:
 - Phenology is the study of periodic biological phenomena.
 - They refer to like events such as the time intervals between mainstem or branch leaves on a plant, unlike events such as the time intervals between plant emergence and formation of flower bud, flower or mature fruit, and/or a duration of process such as the time interval between unfolding or appearance of leaf or internode, and until those organs reach maximum size or length.
 - Therefore, phenology refers to the initiation, differentiation, and development of organs.

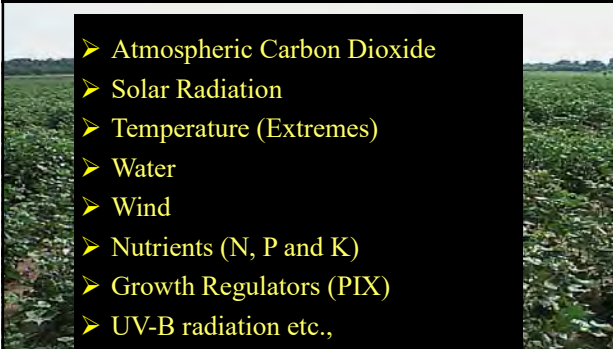
Crop Growth - Importance

- Crop growth:
 - Growth of various organs, in length or area or weight, or crop as whole, is very important in crop production.
 - ✓ Internodes elevate other organs, particularly leaves, for optimum PAR interception.
 - ✓ The size, weight, and quality of individual organs, particularly the final product of a crop, are important.
 - ✓ Any factor (abiotic & biotic) or process (intra-plant) that affects growth of these organs will have profound influence on yield of economic importance.

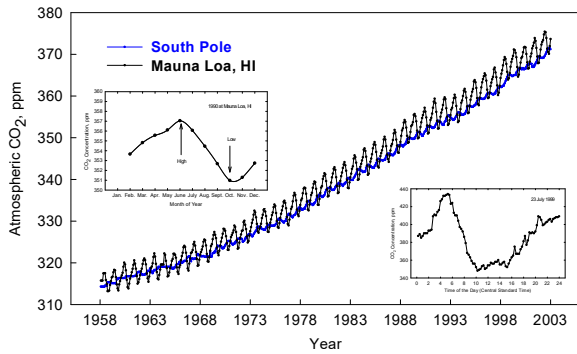


Environmental and Cultural Factors Influencing Crop Growth

- Atmospheric Carbon Dioxide
- Solar Radiation
- Temperature (Extremes)
- Water
- Wind
- Nutrients (N, P and K)
- Growth Regulators (PIX)
- UV-B radiation etc.,

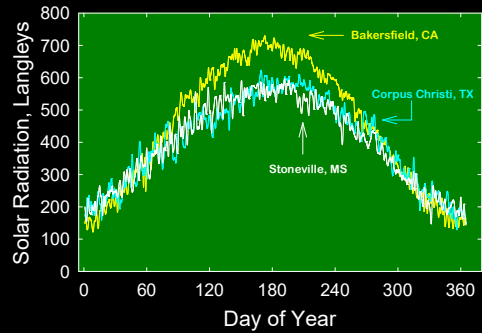


Global Atmospheric CO2 Concentrations Mauna Loa, HI and South Pole

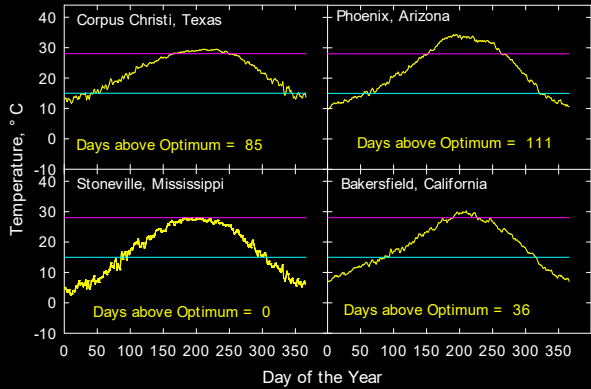


Radiation Conditions - Seasonal Trends

Bakersfield, CA, Corpus Christi, TX and Stoneville, MS

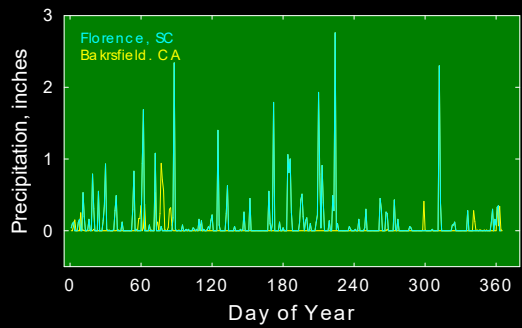


Long-term Average Temperatures for Four US Cotton Producing Areas

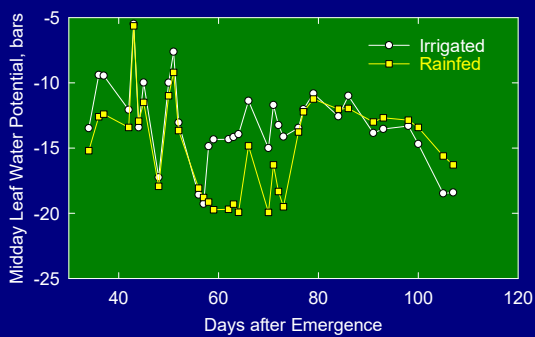


Precipitation - Seasonal Trends

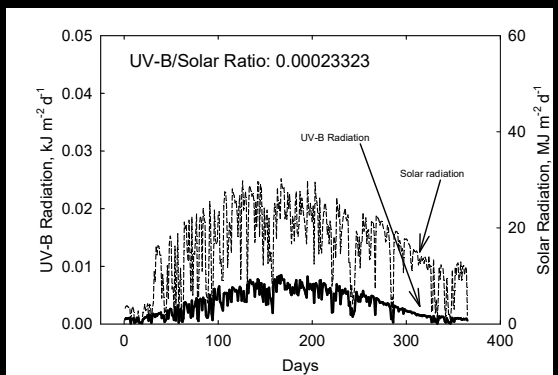
Bakersfield, CA and Florence, SC - 1991



Seasonal Trends - Midday Leaf Water Potential Irrigated and rainfed cotton, MSU North Farm -1995



Seasonal Trends Solar and UV-B Radiation

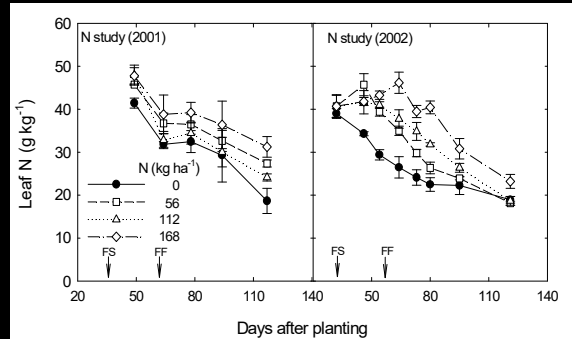


Photosynthesis - Management Factors

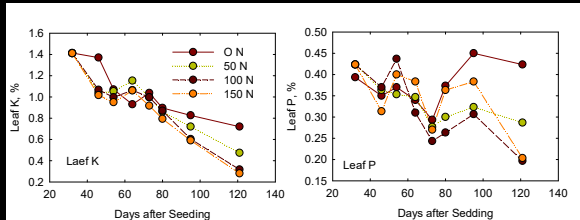


Management factors such as fertilizer application amounts and timings affect nutrient uptake and thus photosynthesis (Leaf N, P, K etc.,)

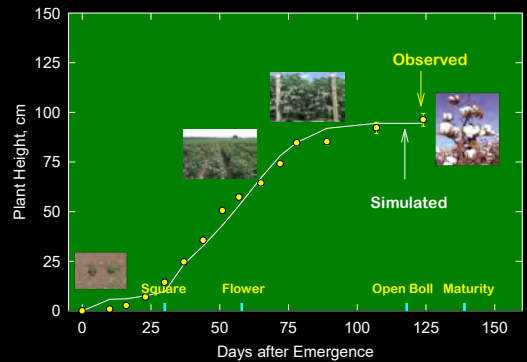
Cultural and Environmental Factors Seasonal Trends – Leaf Nitrogen Concentration



Cultural and Environmental Factors Seasonal Trends – Leaf Potassium and Phosphorus Concentration



Impact of Weather on Plant Growth - Mississippi State - 1992 Temporal Trends in Plant Height - Simulated and Observed



Quantifying the Effects of Environmental Factors on Crop Growth

One way to quantify the effects of environmental factors on growth is to use environmental productivity Index (EPI) concept for growth like the way we used in calculating photosynthesis and phenology

$EPI\text{-growth} = \text{Temperature (potential)} * \text{Nutrient Index (C, N, P, K)}$
 $* \text{Water index} * \text{PPF Index} * \text{UV-B radiation Index} * \text{PGR Index}$
 etc.,

First, we have to define the potential growth for given species or cultivar. Potential growth is defined as the rate of growth (length, area or weight) that takes place at a range of temperatures under optimum environmental conditions (optimum water, nutrient, 0 UV-B etc.) and also during the period when intra-plant competition is also at minimum.

Quantifying the Effects of Environmental Factors on Crop Growth

Then, we have to account for all the environmental factors that limit that potential.

Individual environmental factors affect the potential growth multiplicatively, not additively as in photosynthesis and phenology. For instance, if prolonged water stress causes plants to grow slower, growth of stems and leaves will reflect that condition even if the temperature and other factors are optimum.

The EPI index values for each of the environmental factors, range from 0 when a variable is totally limiting growth to 1 when it does not limit the growth process. The EPI for that given factor represents the fractional limitation due to that particular stress. Therefore, growth rates will be slower as the effect of that particular stress factor becomes more severe.

Quantifying the Effects of Environmental Factors on Crop Growth

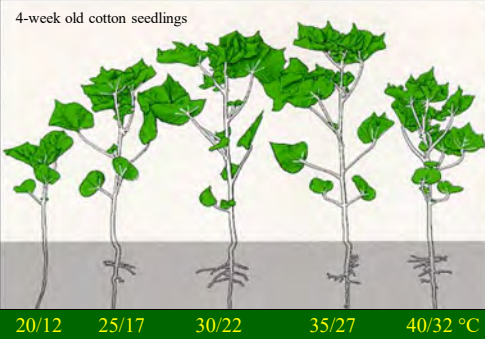
The EPI concept allows one to quantify the effect of environmental factors that limit crop growth in a multi-stress environments or in field conditions.

Cotton – Growth and Development Growth – Potential

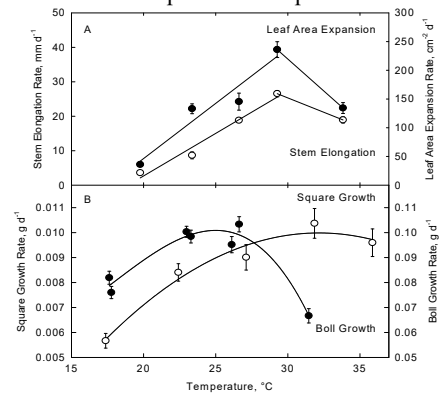


Crop Growth and Development - Environment Response to Temperature

4-week old cotton seedlings

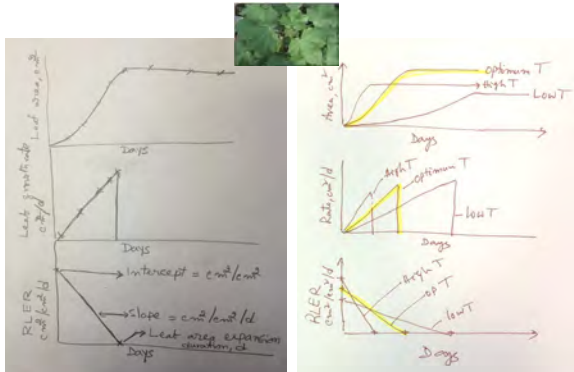


Crop Growth and Development - Environment Response to Temperature

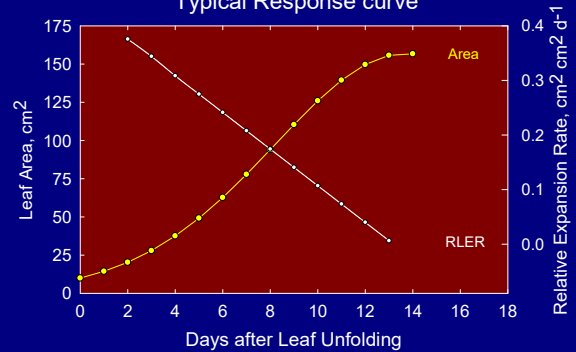


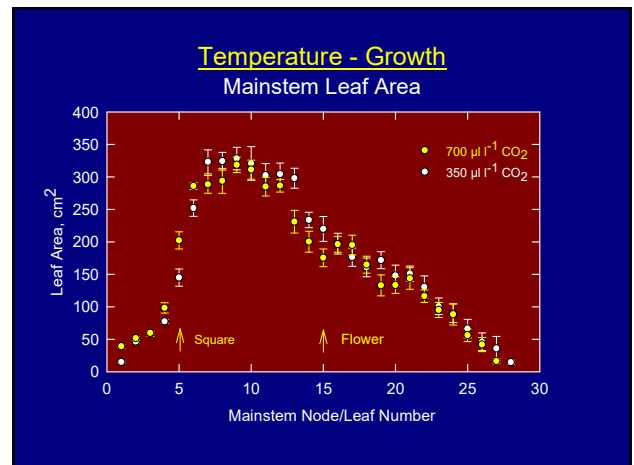
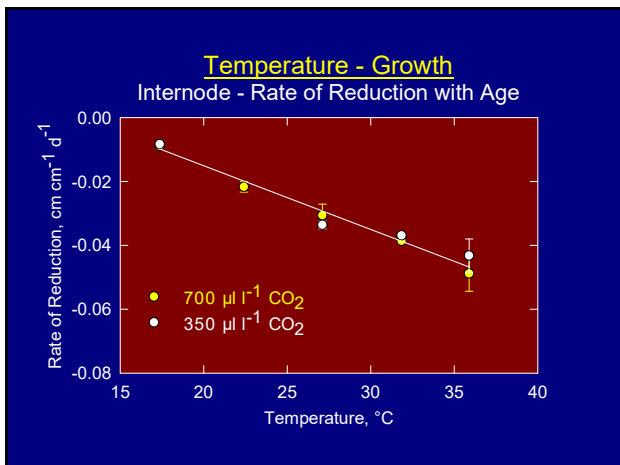
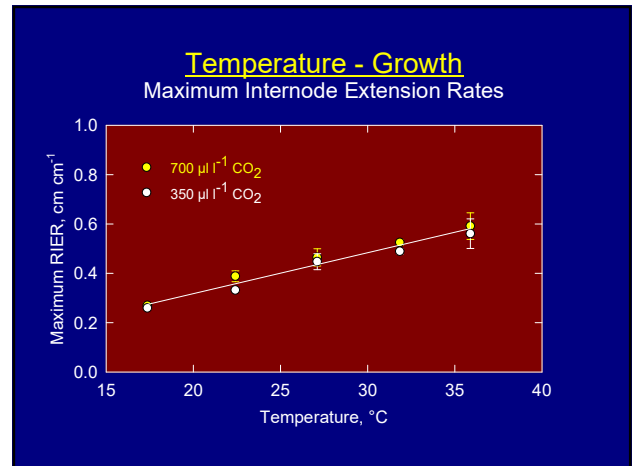
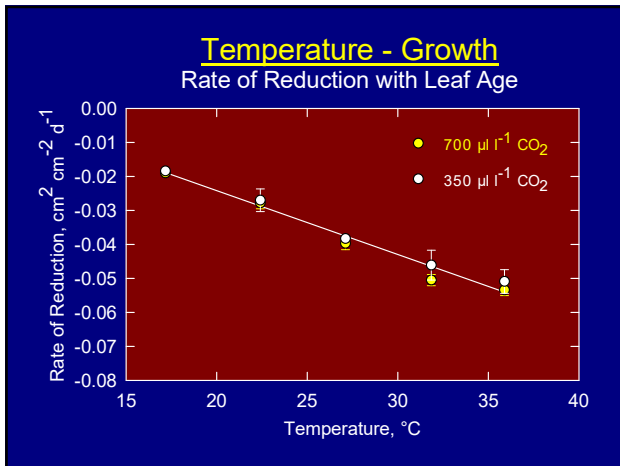
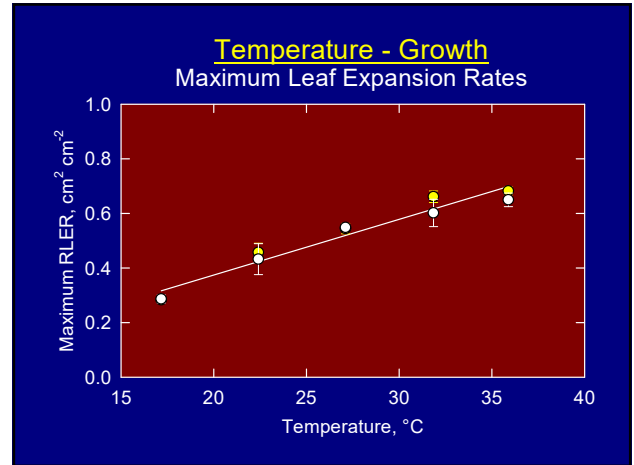
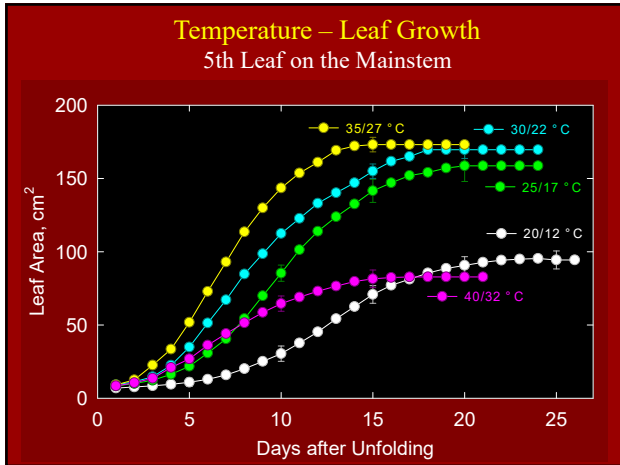
Crop Growth

Understanding leaf growth rates

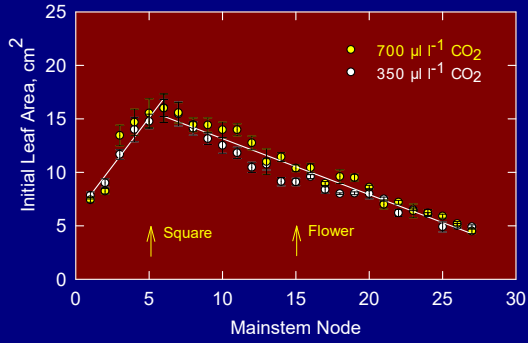


Growth - Leaf Expansion Typical Response curve

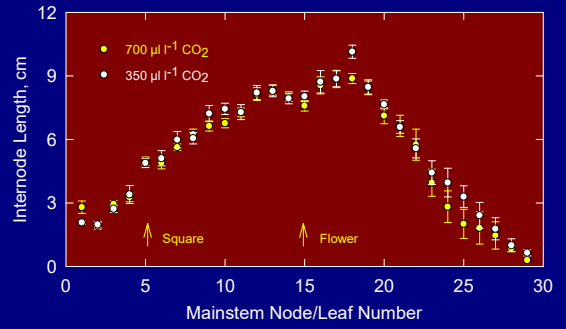




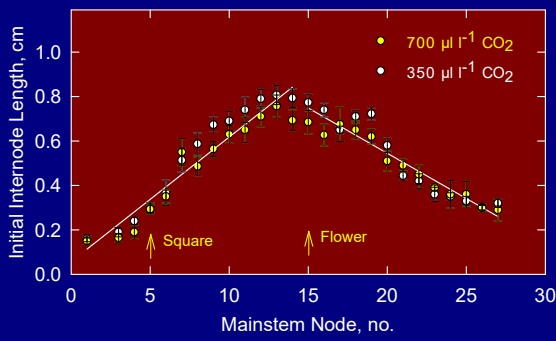
Temperature - Growth
Leaf Area at Leaf Unfolding



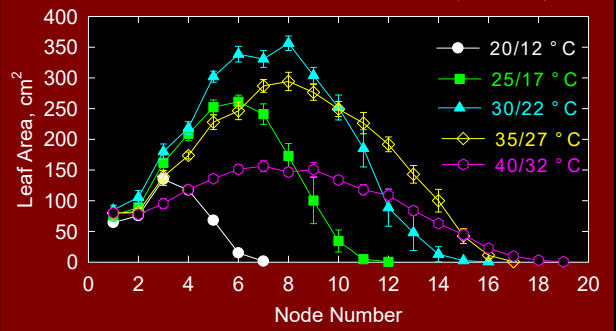
Temperature - Growth
Mainstem Internode Lengths



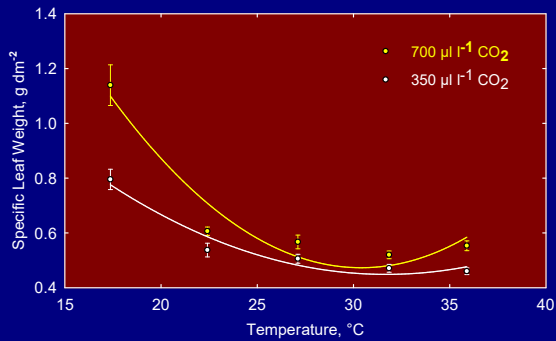
Temperature - Growth
Internode Lengths at Leaf Unfolding



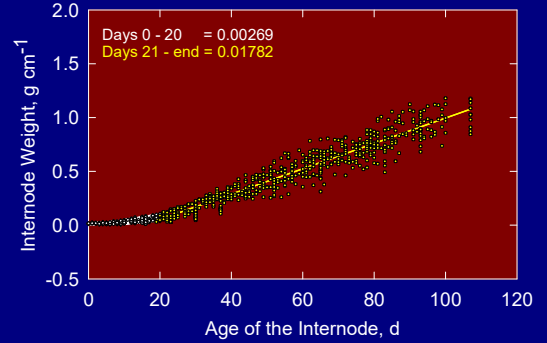
Temperature - Leaf Growth
Profile of Mainstem Leaf Sizes (70 DAE)

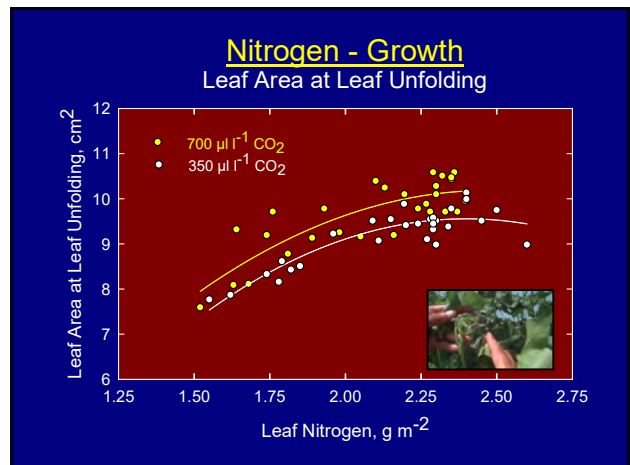
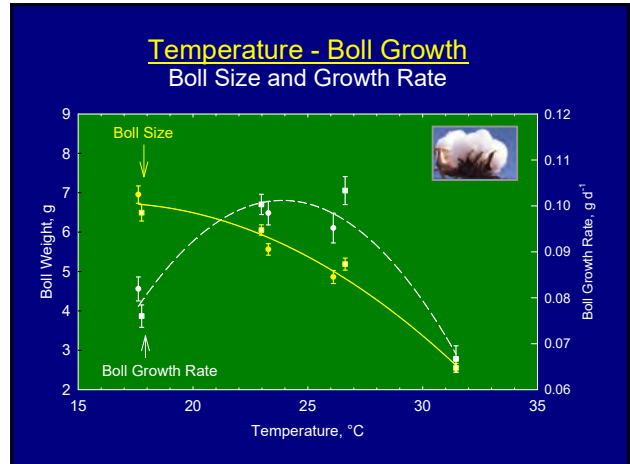
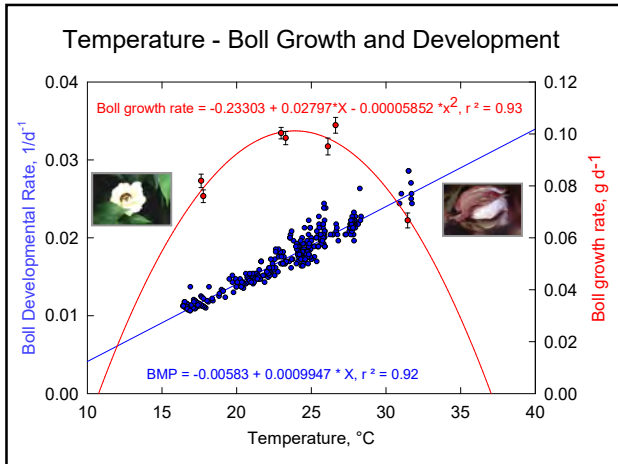
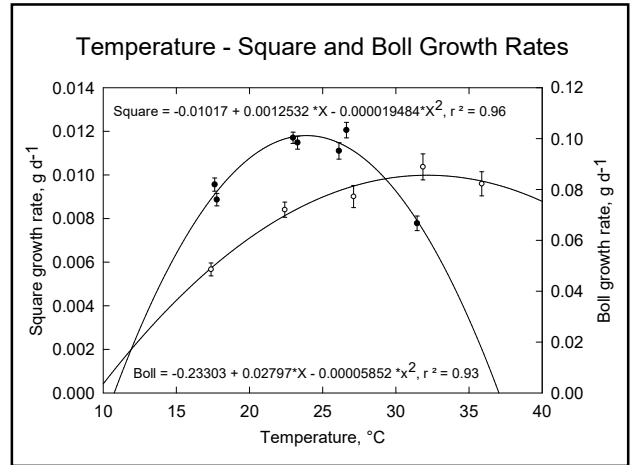
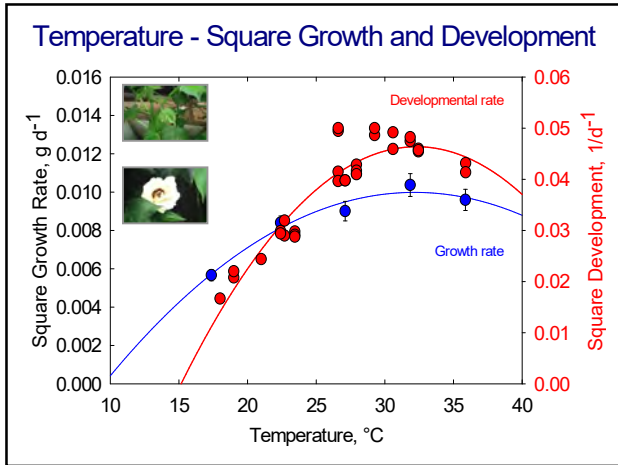


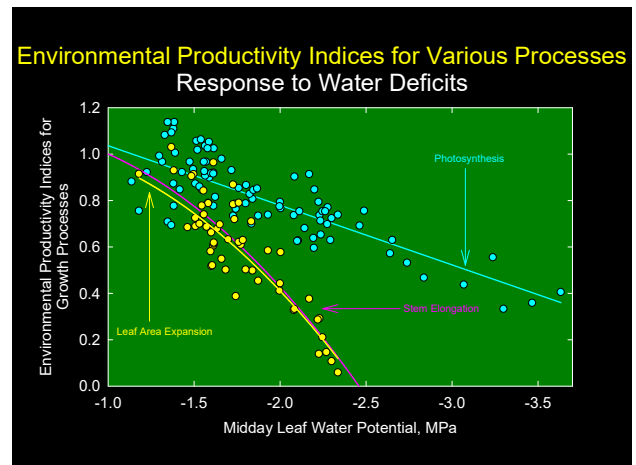
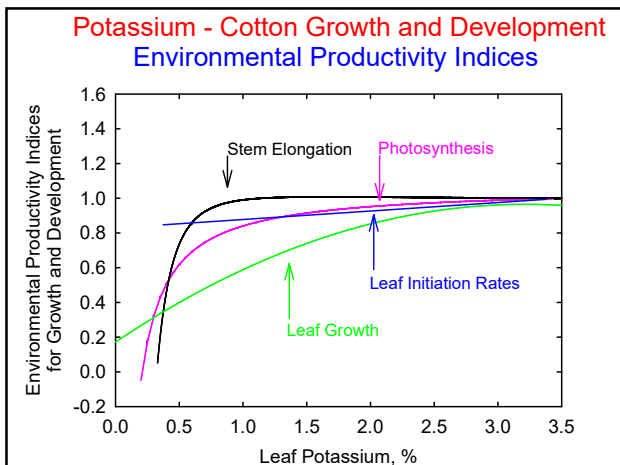
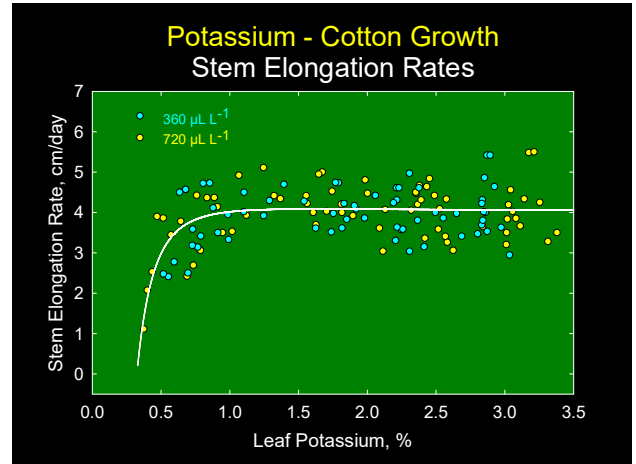
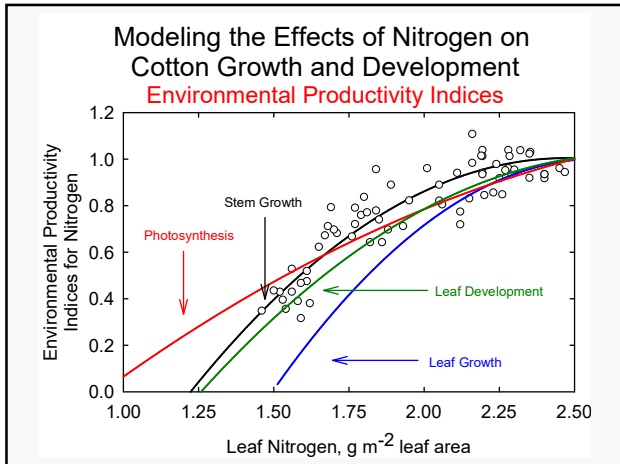
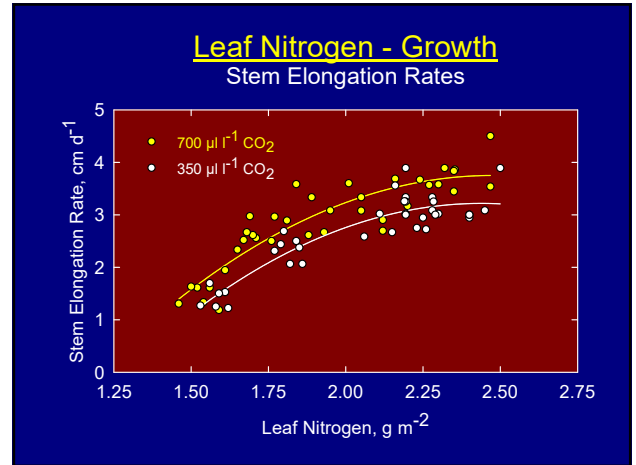
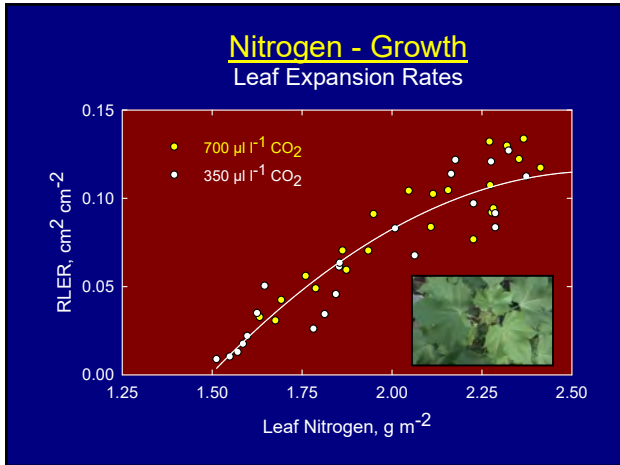
Temperature - Growth
Specific Leaf Weight



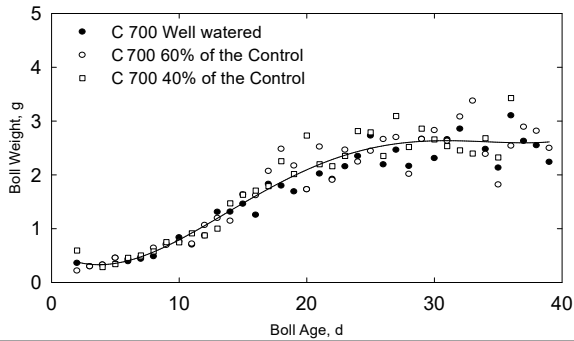
Growth - Mass Accretion
Internodes



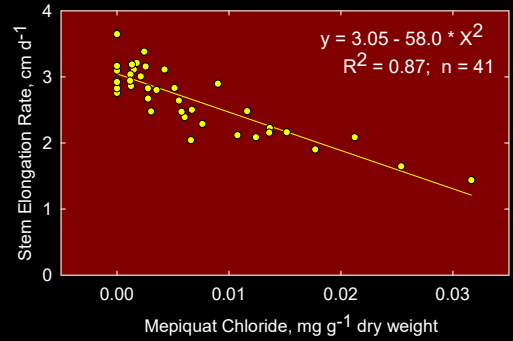




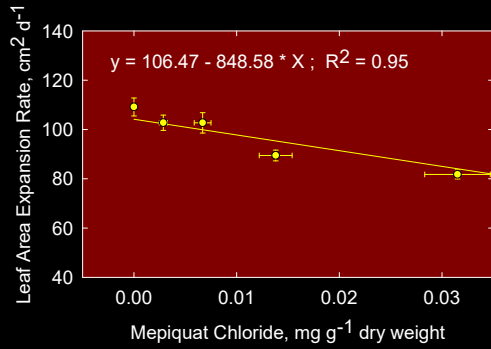
Quantifying the Effects of Environmental Factors on Crop Growth – Water Stress on Fruit Growth



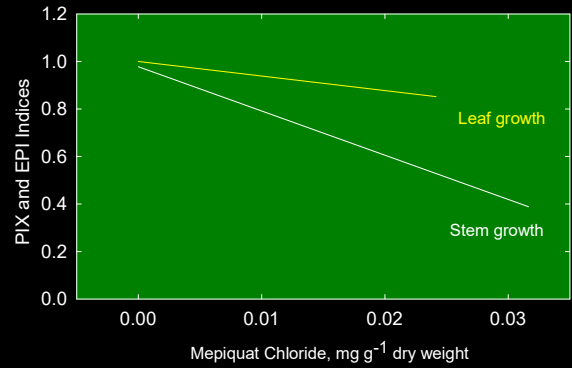
Mepiquat Chloride - Cotton Growth
Plant Height - Stem Extension Rate



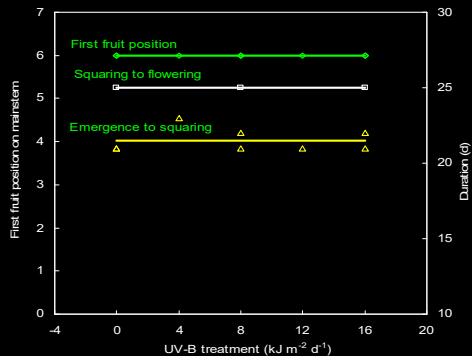
Mepiquat Chloride - Cotton Growth
Leaf Area Development



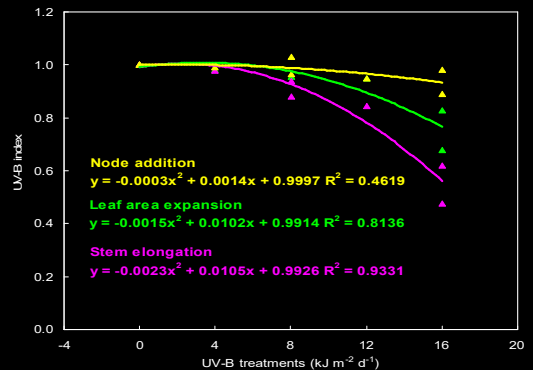
Mepiquat Chloride (PIX) - Growth
EPI Factors



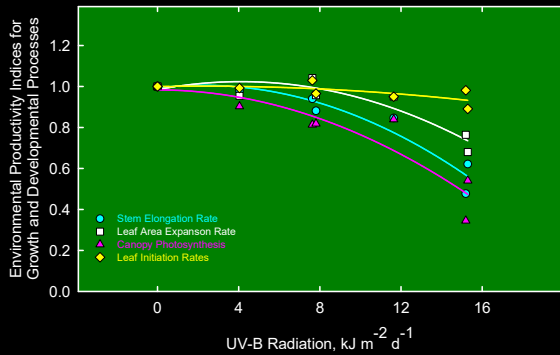
UV-B Radiation – Growth
EPI Factors for various growth Processes



UV-B Radiation – Phenology
EPI Factors for various Developmental Processes



UV-B Radiation – Cotton Growth EPI Factors for various growth Processes



Quantifying the Effects of Environmental Factors Crop Growth

For stem elongation and leaf area expansion:

1. First, we should calculate the potential as a function of temperature under optimum conditions.
2. Then, we need decrease that potential based on environmental factors using the EPI concept for growth.

$$\text{Actual} = \text{Potential value (function of temperature)} * \text{EPI-Water} * \text{EPI-N} * \text{EPI-K} * \text{EPI-PIX} * \text{EPI UVB.}$$

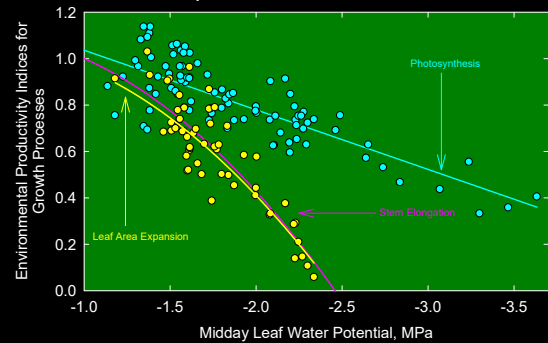
Quantifying the Effects of Environmental Factors on Crop Growth

For stem, leaf, square and boll weight (mass accretion):

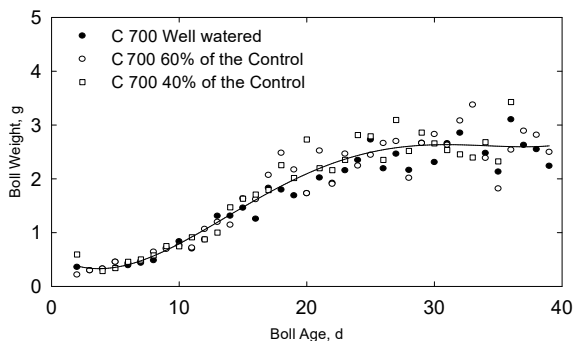
1. First, we should calculate the potential as a function of temperature.
2. Then, decrease that potential based on stress factors only if the reduction is in addition to- or greater than the environmental factor on photosynthesis. Otherwise, we will be accounting the stress effects twice for the dry weight gain; once through a direct effect of environmental factor on photosynthesis and second time through EPI-growth.

$$\text{Actual} = \text{Potential value (function of temperature)} * \text{EPI-Water} * \text{EPI-N} * \text{EPI-K} * \text{EPI-PIX} * \text{EPI UV-B, only if they affect on top of environmental factor effects on photosynthesis.}$$

Environmental Productivity Indices for Various Processes Response to Water Deficits



Quantifying the Effects of Environmental Factors on Crop Growth – Water Stress on Fruit Growth



Quantifying the Effects of Environmental Factors Crop Growth

For modeling or quantification of stem extension or elongation:



We need:

1. Internode node length at node initiation.
2. The effect of environmental factors on those lengths.
3. The potential extension rate parameters (slope and intercept as a function of temperature)
4. The EPI-growth factors to decrease those potentials.

Quantifying the Effects of Environmental Factors Crop Growth

For modeling leaf area development:



We need:

1. Leaf areas at leaf unfolding
2. The effect of environmental factors on those areas
3. The potential expansion rate parameters (slope and intercept as a function of temperature)
4. The EPI-growth factors to decrease those potentials.

Quantifying the Effects of Environmental Factors Crop Growth

For modeling leaf and internode, square and boll
growth rates (mass accretion):

We need:

The potential expansion rate parameters as a
function of temperature.

Crop Growth and Development Growth and Environment

- The growth (rates) organs or the plant as whole, in general, is very complex.
- Understanding the effects of environmental factors on crop growth, and quantifying their effects on these vital processes will provide meaningful insight on how a crop will grow in natural environment.
- Environmental productivity index concept is very effective and useful in understanding and in quantifying the multiple stress factors on crop growth and in modeling.