Environmental Plant Physiology
Summary

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Mississippi State, MS
Environmental Plant Physiology
Objectives

• The objectives of this course are to learn plant responses to abiotic stresses, particularly plant growth and development, and to learn modeling methodologies on how to integrate those plant processes under multiple stress conditions.

• At the end, the students are expected to:
  
  ✓ understand individual as well as interactive abiotic stress effects on photosynthesis, respiration, growth, development and finally yield.

  ✓ understand on how to develop methodologies to integrate multiple stress factor effects on various plant/canopy processes.
Trends That Shape Our Future
Trends, Signs and Signatures from the Earth
Past, Present and Future World Population

![Graph of World Population Over Time](image-url)


**Trends, Signs and Signatures from the Earth**

**Present and Future World Population Trends**

Population, millions

<table>
<thead>
<tr>
<th>Region</th>
<th>2000</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asia (less China and India)</td>
<td>1,520</td>
<td>2,367</td>
</tr>
<tr>
<td>China</td>
<td>1,301</td>
<td>1,437</td>
</tr>
<tr>
<td>India</td>
<td>1,087</td>
<td>1,628</td>
</tr>
<tr>
<td>Africa</td>
<td>885</td>
<td>1,941</td>
</tr>
<tr>
<td>Europe</td>
<td>728</td>
<td>668</td>
</tr>
<tr>
<td>Latin America</td>
<td>549</td>
<td>778</td>
</tr>
<tr>
<td>North America</td>
<td>326</td>
<td>457</td>
</tr>
</tbody>
</table>

**Trends, Signs and Signatures from the Earth**

- **56%**
- **10%**
- **50%**
- **120%**

**Trends, Signs and Signatures from the Earth**

- **-5%**
- **42%**
- **39%**
Trends, Signs and Signatures from the Earth
Global Major Foods – Per Capita Consumption

Year
Conversion, lb/person
100 150 200 250 300 350 400 450

Selected fruits = 1.95 lb/year
Vegetables = 3.21 lb/year
Meat and Poultry = 0.65 lb/year
Flour and Cereals = 2.70 lb/year
Trends, Signs and Signatures from the Earth
Global Major Foods – Meat and Poultry Production

Meat and Poultry Production

Meat and Poultry Production Relative Trends

1961 to 2007: Million t
Poultry = 9 and 87
Meat = 71 and 286
Trends, Signs and Signatures from the Earth
Maize - Production and Yield – Selected Counties

Yield
- USA: 156% @ 114 kg yr⁻¹
- China: 335% @ 100 kg yr⁻¹
- Brazil: 157% @ 47 kg yr⁻¹

Production
- USA: 226% @ 3.90 MMt yr⁻¹
- China: 631% @ 2.77 MMt yr⁻¹
- Brazil: 364% @ 0.73 MMt yr⁻¹

P= 67%, and A= 46%
Trends, Signs and Signatures from the Earth
Rice - Production and Yield – Selected Counties

China: 205% @ 102 kg yr\(^{-1}\)
Indonesia: 156% @ 77 kg yr\(^{-1}\)
India: 90% @ 42 kg yr\(^{-1}\)

China: 232% @ 2.98 MMt yr\(^{-1}\)
India: 339% @ 2.15 MMt yr\(^{-1}\)
Indonesia: 132% @ 1.12 MMt yr\(^{-1}\)

P = 60%, and A = 55%
Trends, Signs and Signatures from the Earth
Management Practices

**Crop rotations**

Morrow plots: East-central Illinois

- Corn-oats-hay rotation
- Continuous corn

**Fertility management**

Sanborn Field: Central Missouri

- Estimated to 4% in 1888

Reicosky et al. 2000
## Year 2000

<table>
<thead>
<tr>
<th>Country</th>
<th>Cropland area</th>
<th>Irrigated area</th>
<th>Salinized area</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>124.0</td>
<td>54.4 (22%)</td>
<td>7-8 (14%)</td>
</tr>
<tr>
<td>India</td>
<td>161.8</td>
<td>54.8 (31%)</td>
<td>10-30 (50%)</td>
</tr>
<tr>
<td>USA</td>
<td>177.0</td>
<td>22.4 (13%)</td>
<td>4.5 -6 (15%)</td>
</tr>
<tr>
<td>USSR</td>
<td>204.1</td>
<td>19.9 (2%)</td>
<td>2.5-4.5 (21%)</td>
</tr>
<tr>
<td>World</td>
<td>1364.2</td>
<td>271.7 (21%)</td>
<td>62-82 (37%)</td>
</tr>
</tbody>
</table>

Percent change since 1985
Trends, Signs and Signatures from the Earth
Population, cereal yield, arable and irrigated area, N use

<table>
<thead>
<tr>
<th>Year</th>
<th>Cereal yield</th>
<th>Arable land area</th>
<th>Irrigated land area</th>
<th>Population</th>
<th>Fertilizer use</th>
</tr>
</thead>
<tbody>
<tr>
<td>1955</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1960</td>
<td></td>
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</tr>
<tr>
<td>1965</td>
<td></td>
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<tr>
<td>1970</td>
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<tr>
<td>1975</td>
<td></td>
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<tr>
<td>1980</td>
<td></td>
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</tr>
<tr>
<td>1985</td>
<td></td>
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</tr>
<tr>
<td>1990</td>
<td></td>
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<tr>
<td>1995</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>2000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2000 values are:
- Cereal yield = 2.25
- Arable area = 1.09
- Irrigated area = 1.98
- Population = 1.97
- Fertilizer use = 4.33
We must develop the capacity to feed 10 billion people within in the next 40 to 50 years.

- The average world current cereal yield is about 3 tons per ha for about 6 billion people.
- We need about 4 tons per ha for 8 billion (33 % more than the current), and 5 tons per ha for 10 billion (67 % more than the current).
Routes to Greater Food Production

- Increase in the area of land under cultivation.
- Increase in the number of crops per hectare per year (mostly practiced in tropics, requires access to irrigation, high input use, short season cultivars, and others such as labor, pest and disease control may be a problem).
- Displacement of lower yielding crops by higher yielding ones (done since the dawn of domestication).
- Efficiency of crop production in terms of:
  Per unit of land area (yield per ha)
  Per unit of time
  Per unit of inputs such as fertilizers, water and labor etc.
Here comes the greatest challenge of our time, The Global Climate Change
Environmental Stresses and Plant Growing Conditions
Environmental and Cultural Factors Limiting Potential Yields

- Atmospheric carbon dioxide
- Solar radiation
- Temperature (extremes)
- Water (irrigation and rainfall)
- Wind
- Nutrients (N, P, K, and other nutrients)
- Others, Ultra-violet radiation, ozone etc.,
- Growth regulators (such as PIX)
<table>
<thead>
<tr>
<th>Limitation</th>
<th>Area of world soil subject to limitation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drought</td>
<td>27.9</td>
</tr>
<tr>
<td>Shallow soil</td>
<td>24.2</td>
</tr>
<tr>
<td>Mineral excess or deficiency</td>
<td>22.5</td>
</tr>
<tr>
<td>Flooding</td>
<td>12.2</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>3.1</td>
</tr>
<tr>
<td>None</td>
<td>10.1</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
</tr>
<tr>
<td>Temperature</td>
<td>14.8 (over laps with other stresses)</td>
</tr>
</tbody>
</table>
Environmental Plant Physiology

Chapter 1

- Atmospheric carbon dioxide
- Solar radiation
- Temperature (Including extremes)
- Water
- Wind
- Nutrients
- Other factors such as ozone
- Plant growth regulators
- The facilities and tools
Chapter 2

Photosynthesis and the environment

• The Environmental productivity Index (EPI) concept.
• The photosynthesis - Species variability.
• Photosynthesis and aging process.
• Respiration.
Chapter 3

Crop growth and development

• Phenology
• Growth of various organs and whole plants.
• The concept of environmental productivity index in quantifying crop growth and development in response to the environment.
Chapter 4

Scaling of processes from leaves to whole plant, canopies or ecosystems.

Chapter 5

Special topics include:

• Remote sensing and environmental plant physiology.
Environmental limiting crop growth, development and yield

- Atmospheric Carbon Dioxide
- Solar Radiation
- Temperature
- Water (indirect)
- Wind
- Nutrients (N, P, K)
- Ozone, UV-B etc.,
- Growth Regulators
Environmental limiting crop growth, development and yield

- Atmospheric Carbon Dioxide
- Solar Radiation
- Temperature
- Water (indirect)
- Wind
- Nutrients (N, P, K)
- Ozone, UV-B etc.,
- Growth Regulators
Global Carbon Dioxide Concentrations

Trends over the last two centuries
CO₂ Concentration Estimates for Preliminary SRES Scenarios
A Hierarchy of Plant Responses to CO₂

Atmospheric CO₂

- Stomatal Resistance
- Transpiration
- Tissue Water Potential

Photosynthesis

- Tissue Temperature

Photorespiration

Carbon Availability

Growth and Development

Yield
Environmental limiting crop growth, development and yield

- Atmospheric Carbon Dioxide
- Solar Radiation
- Temperature
- Water (indirect)
- Wind
- Nutrients (N, P, K)
- Ozone, UV-B etc.,
- Growth Regulators
## Table 1.6. Effect of radiation on plant life. (Ross 1981)

<table>
<thead>
<tr>
<th>Spectral region</th>
<th>Wavelength (nm)</th>
<th>Percent of solar radiant energy</th>
<th>Photosynthetic</th>
<th>Effects of radiation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Photomorphogenetic</td>
<td>Photodestructive</td>
</tr>
<tr>
<td>Ultraviolet</td>
<td>290 – 380</td>
<td>0 – 4</td>
<td>Insignificant</td>
<td>Slight</td>
</tr>
<tr>
<td>Photosynthetically active range (PhAR)</td>
<td>380 – 710</td>
<td>21 – 46&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Significant</td>
<td>Significant</td>
</tr>
<tr>
<td>Infrared</td>
<td>750 – 4000</td>
<td>50 – 79&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Significant</td>
<td>Significant</td>
</tr>
<tr>
<td>Longwave radiation</td>
<td>4000 – 100000</td>
<td></td>
<td>Insignificant</td>
<td>Insignificant</td>
</tr>
</tbody>
</table>

<sup>a</sup> Depending on position of sun and degree of cloud cover.
Net Photosynthesis and Available Light Intensity

Time of the Day (Central Standard Time)

PPFD, µmol m\(^{-2}\) s\(^{-1}\)

Carbon Exchange Rate, mg CO\(_2\) m\(^{-2}\) s\(^{-1}\)

Solar Radiation

Maize, DAE 37

360 µL L\(^{-1}\)

Maize, DAE 37
Photosynthesis and Solar Radiation

Species variability

Am – Amaranthus
Au – Aubergine
Ba – Barley
Be – Bean
Bg – Bermudagrass
Ca – Cabbage
Ch – Chrysanthimum
Co – Cotton
Cu – Cucumber
Pe – Pepper
Ro – Rose
Ry – Ryegrass
So – Sobeann
To - Tomato
Leaf and canopy development and aging process

Leaf

- 12-day
- 5-day
- 2-day
- 8-day
- Emerging leaf
- About to abscise

Canopies

- Emergence
- Squaring
- Flowering
- Mature crop
Solar Radiation and Dry Matter Production

Figure 1 Accumulated monthly mean values of net primary production plotted against the accumulated quantity of total solar radiation (all wavelengths) intercepted by the same communities. Solid lines are the best-fitting straight lines to the illustrated data points. Data are for: (●) monotypic stands of *Echinochloa polystachya* on the Amazon floodplain near Manaus, Brazil (Piedade et al., 1991); (▲) monotypic stands of *Distichlis spicata* on saline grassland close to Mexico City (Jones et al., 1992); and (■) mixed C₄ grass stands codominated by *Eulalia trispicata* and *Lophopogon intermedius* in moist savanna near Hat Yai, Thailand (Kamnalrut and Evenson, 1992). The broken lines indicate the maxima suggested for the two photosynthetic types (after Monteith, 1978). Data redrawn from Piedade et al. (1991) and Jones et al. (1992).
Effects of Multiple Environmental Factors on Crop Growth and Developmental Aspects

- Introduced Environmental Productivity Index (EPI) concept.
- Photosynthesis
- Crop Phenology or Development
- Crop Growth
- Reproductive Biology
Canopy Photosynthesis - Growing Season
Accounting for environmental factors using EPI concept

If the crop can intercept all the radiation

Days after Emergence

Photosynthesis, g CO₂ m⁻² d⁻¹
Canopy Photosynthesis - Growing Season

Accounting for environmental factors using EPI concept

If the crop can intercept all the radiation

Incoming Solar

Intercepted Solar

Photonsynthesis, g CO₂ m⁻² d⁻¹

Days after Emergence

0 20 40 60 80 100 120 140 160
Canopy Photosynthesis - Growing Season
Accounting for environmental factors using EPI concept

If the crop can intercept all the radiation

Photons per unit area and time (g CO₂ m⁻² d⁻¹)

Days after Emergence

Incoming Solar
Intercepted Solar (Potential)
Potential * UV-B
Potential * UV-B * T
Potential * UV-B * T * LWP
Potential * UV-B * T * LWP * N
Potential * UV-B * T * LWP * N * K
Radiation Totals for the 1992 Growing season
Mississippi State – North Farm

<table>
<thead>
<tr>
<th>Variable</th>
<th>Amount, MJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Incoming Radiation</td>
<td>2842</td>
</tr>
<tr>
<td>Intercepted Radiation</td>
<td>1551</td>
</tr>
<tr>
<td>Percent Intercepted</td>
<td>55</td>
</tr>
</tbody>
</table>
### Photosynthesis – EPI Concept
#### Accounting for Individual Factors

<table>
<thead>
<tr>
<th>Variable</th>
<th>Amount, g CO2 m⁻² season⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incoming R</td>
<td>19644</td>
</tr>
<tr>
<td>Intercepted R</td>
<td>11441 (100%)</td>
</tr>
<tr>
<td>Int. R * UV-B</td>
<td>10448 (9%)</td>
</tr>
<tr>
<td>Int. R * T</td>
<td>10139 (11%)</td>
</tr>
<tr>
<td>Int. R * W</td>
<td>9783  (14%)</td>
</tr>
<tr>
<td>Int. R * N</td>
<td>8986  (21%)</td>
</tr>
<tr>
<td>Int. R * K</td>
<td>10841 (5%)</td>
</tr>
</tbody>
</table>
### Photosynthesis – EPI Concept

**Accounting for Multiple Factors**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Amount, g CO2 m⁻² season⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incoming R</td>
<td>19644</td>
</tr>
<tr>
<td>Intercepted R</td>
<td>11441 (100%)</td>
</tr>
<tr>
<td>Int. R* UV-B</td>
<td>10230 (9%)</td>
</tr>
<tr>
<td>Int. R* UV-B*T</td>
<td>9153 (20%)</td>
</tr>
<tr>
<td>Int. R* UV-B<em>T</em>W</td>
<td>7551 (34%)</td>
</tr>
<tr>
<td>Int. R<em>UV-B</em>T<em>W</em>N</td>
<td>6292 (55%)</td>
</tr>
<tr>
<td>Int. R<em>UV-B</em>T<em>W</em> K</td>
<td>4576 (60%)</td>
</tr>
</tbody>
</table>

*Actual amount*
Environmental limiting crop growth, development and yield

- Atmospheric Carbon Dioxide
- Solar Radiation
- Temperature
- Water (indirect)
- Wind
- Nutrients (N, P, K)
- Ozone, UV-B etc.,
- Growth Regulators
Long-Term Average Temperatures

Day of the Year

Temperature, °C

Phoenix, AZ
Maros, Indonesia
Stoneville, MS
Temperature Conditions - Diurnal Trends
Mississippi State, MS - 1995

Temperature, °C

Hours (CST)

0 2 4 6 8 10 12 14 16 18 20 22 24

0 5 10 15 20 25 30 35 40

19 Aug. 1995
2 May, 1995
23 Sep. 1995
Central **Temperature Estimates** Plus Extremes for the Preliminary SRES Scenarios

![Temperature Estimate Chart](chart.png)
Environment Factors

Temperature:

- **Strongly Affects:**
  - Phenology
  - Vegetative growth, LAI, LAD
  - Fruit Growth and Retention
  - Respiration
  - Water-loss and Water-Use

- **Moderately Affects:**
  - Photosynthesis on a canopy basis
High-temperature Injury

Heat-blasted Cotton Squares
California’s San Joaquin Valley

Heat-blasted Cotton Flowers and Squares – Arizona

Figure 7. Heat-blasted squares in California’s San Joaquin Valley. (Photo: R. Vargas)
Environmental limiting crop growth, development and yield

- Atmospheric Carbon Dioxide
- Solar Radiation
- Temperature
- Water (indirect)
- Wind
- Nutrients (N, P, K)
- Ozone, UV-B etc.,
- Growth Regulators
Water plays essential roles in plants as a:

- Constituent
- Solvent
- Reactant in various chemical processes
- Maintenance of turgidity

The physiological importance of water is reflected in its ecological importance.

The distribution plants over the earth’s surface is controlled by the availability of the water (amount and seasonal distribution of precipitation) where ever temperature permits growth.
Figure 10

Relative Precipitation Changes (%/°C) Mean of 15 Models

Dec-Jan-Feb

Mar-Apr-May

Jun-Jul-Aug

Sep-Oct-Nov

Legend: -4 -2 0 2 4 6 8
Role of water in cotton

Water deficit

- Cell expansion
- Mesophyll Resistance
- Stomatal Resistance
- Cell division & differentiation

Leaf GR
Stem GR (height)
Root GR
Rate of Photosynthesis
Rate of Transpiration
Rate of squaring
Node production
Boll GR

Sequence of events

- LAI
- Canopy photosynthesis
- Vegetative yield
- Seasonal transpiration
- Economic yield
- bolls
- shedding
Environment Factors

Water Deficits:

- **Strongly affects:**
  - Vegetative growth, LAI, LAD
  - Fruit Growth and Retention
  - Water-loss and Water-Use
  - Photosynthesis

- **Moderately affects certain phenological events:**
  - Phenology (leaf development)
Environment – Wind and Hail
Environmental limiting crop growth, development and yield

- Atmospheric Carbon Dioxide
- Solar Radiation
- Temperature
- Water (indirect)
- Wind
- Nutrients (N, P, K)
- Ozone, UV-B etc.,
- Growth Regulators
Photosynthesis - Variability Among Species
Response to Leaf Nitrogen

Leaf Nitrogen, g m\(^{-2}\)

Photosynthesis, mg CO\(_2\) m\(^{-2}\) s\(^{-1}\)

Maize
Sorghum
Cotton
Sunflower
Rice
Soybean
Leaf Nitrogen, g m\(^{-2}\) leaf area

Environmental Productivity Indices for Nitrogen

Leaf Growth
Leaf Development
Stem Growth
Photosynthesis

Environment - Nitrogen

Leaf Nitrogen, g m\(^{-2}\) leaf area
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Leaf N, g m(^{-2})</th>
<th>Photosynthesis</th>
<th>Stem growth</th>
<th>Leaf growth</th>
<th>Leaf Development</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>2.0</td>
<td>12</td>
<td>14</td>
<td>18</td>
<td>&gt;99</td>
<td>12</td>
</tr>
<tr>
<td>1.5</td>
<td>53</td>
<td>60</td>
<td>&gt;99</td>
<td>68</td>
<td></td>
</tr>
<tr>
<td>1.2</td>
<td>76</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>
Figure 2  The effect of N on number of main-stem nodes, boll number per plant, leaf area, and boll weight (Jackson and Gerik, 1990).
Environment Factors

Fertilizers Deficits - Potassium:

- **Strongly Affects:**
  -- Leaf growth, LAI, LAD
  -- Fruit Retention

- **Moderately Affects:**
  -- Photosynthesis
  -- Stem growth
Environment - Nutrients

Potassium - Cotton Growth and Development

Environmental Productivity Indices

Leaf Potassium, %

Environmental Productivity Indices for Growth and Development

- Leaf Growth
- Stem Elongation
- Photosynthesis
- Leaf Initiation Rates

Leaf Potassium, %
Ultraviolet-B Radiation:

- **Strongly Affects:**
  - Photosynthesis
  - Stem growth

- **Moderately Affects:**
  - Leaf growth
  - Leaf aging

- **No Effects:**
  - Phenology
Environmental limiting crop growth, development and yield

- Atmospheric Carbon Dioxide
- Solar Radiation
- Temperature
- Water (indirect)
- Wind
- Nutrients (N, P, K)
- Ozone, UV-B etc.,
- Growth Regulators
Solar Radiation and Plant Life

For plants, radiation is:

- A source of energy *(photoenergetic effect).*
- Stimulus for development *(photocybernetic effect).*
- Stress factor *(photodestructive effect).*
## Effects of Radiation on Plant Life

<table>
<thead>
<tr>
<th>Spectral Region</th>
<th>Wavelength (nm)</th>
<th>%</th>
<th>Photosynthesis</th>
<th>Photomorphogenic</th>
<th>Photodestructive</th>
<th>Thermal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultraviolet</td>
<td>290-380</td>
<td>0-4</td>
<td>IS</td>
<td>Slight</td>
<td>S</td>
<td>IS</td>
</tr>
<tr>
<td>PAR</td>
<td>380-710</td>
<td>21-46</td>
<td>S</td>
<td>S</td>
<td>Slight</td>
<td>S</td>
</tr>
<tr>
<td>Infrared</td>
<td>750-4000</td>
<td>50-79</td>
<td>IS</td>
<td>S</td>
<td>IS</td>
<td>S</td>
</tr>
<tr>
<td>Longwave</td>
<td>4000-100000</td>
<td></td>
<td>IS</td>
<td>IS</td>
<td>IS</td>
<td>S</td>
</tr>
</tbody>
</table>

*IS = Insignificant, S = Significant*
Ultraviolet Radiation

- **UVC**: <280), **UVB**: 280-320, and **UVA**: 320-400.
- UVA is not absorbed by ozone.
- UVB is mostly absorbed by ozone, although some reaches the Earth.
- UVC is completely absorbed by ozone and normal oxygen.
Why are we concerned with UV now?

The Ozone Depletion Process

1. CFCs released
2. CFCs rise into ozone layer
3. UV releases Cl from CFCs
4. Cl destroys ozone
5. Depleted ozone -> more UV
6. More UV -> more skin cancer
USDA – UV Radiation Monitoring Program
Satellite Based Ozone levels - 2001

EP/TOMS Total Ozone Sep 17, 2001

Dobson Units
Dark Gray < 100, Red > 500 DU

NASA
UV-B Radiation – Growth

EPI Factors for various growth Processes

- First fruit position
- Squaring to flowering
- Emergence to squaring

UV-B treatment (kJ m\(^{-2}\) d\(^{-1}\))

First fruit position on mainstem

Duration (d)
**Stem elongation**

\[ y = -0.0023x^2 + 0.0105x + 0.9926 \]

\[ R^2 = 0.9331 \]

**Leaf area expansion**

\[ y = -0.0015x^2 + 0.0102x + 0.9914 \]

\[ R^2 = 0.8136 \]

**Node addition**

\[ y = -0.0003x^2 + 0.0014x + 0.9997 \]

\[ R^2 = 0.4619 \]

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**UV-B Radiation – Phenology**

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

EPI Factors for various growth Processes

- Canopy Phs = -0.0018x^2 - 0.0043x + 0.9802 \( R^2 = 0.9139 \)
- Total DW = -0.0024x^2 + 0.0021x + 0.9856 \( R^2 = 0.9146 \)
- Total Boll No. = -0.0023x^2 - 0.0086x + 1
- Bolls retained = -0.0015x^2 + 0.0026x + 1
- Leaves retained = -0.0013x^2 + 0.008x + 1

UV-B treatments (kJ m^{-2} d^{-1})
Environmental limiting crop growth, development and yield

- Atmospheric Carbon Dioxide
- Solar Radiation
- Temperature
- Water (indirect)
- Wind
- Nutrients (N, P, K)
- Ozone, UV-B etc.,
- Growth Regulators
Environment Factors

Growth Regulators - Mepiquat Chloride (PIX):

- Moderately Affects:
  -- Leaf, stem and branch growth and LAI

- Slightly Affects:
  -- Photosynthesis
Mepiquat Chloride (PIX) - Growth

EPI Factors

Mepiquat Chloride, mg g\(^{-1}\) dry weight

Leaf growth
Photosynthesis
Stem growth
Environmental Plant Physiology and Remote Sensing

• Special topics
  ➢ Remote sensing
    ✓ Introduction to remote sensing
    ✓ Interrelationships between stress physiology, crop growth condition and remote sensing signatures.
Technology Fusion and Delivery System

Crop Models ↔ GIS

Related database
- Modeling forces the organization of known information and concepts.

- Although we may not know enough to develop a comprehensive model that includes all aspects of the farm or crop production system, modeling some meaningful portions of the system provides clarity.

- For a model to correctly predict plant responses to physical conditions, the concepts and the response functions must be appropriately assembled.
• Critical environment-genotype relations should be incorporated into the model.

• When a crop model is based on appropriate concepts and processes it will have the predictive capability in new environments, and can be used either alone or with other emerging newer technologies to disseminate useful production information.

• Also, crop models should be integrated with other related technologies for technology integration and delivery.
Environmental Plant Physiology
Summary and Conclusions

• To study the effects of environmental factors on growth, development and other processes, we need:

  ✓ Controlled environmental facilities with realistic environmental conditions including solar radiation.

  ✓ Breakdown whole systems into sub-systems and study the influence of environmental factors on those subsystems.

  ✓ Develop some concepts such as EPI to quantify the effects of multiple environmental factors on subsystems.

  ✓ Integrate sub-systems into coherent whole plant/field/ecosystem system-level models/tools.
Environmental Plant Physiology
Summary and Conclusions

• Validated/integrated system simulation models will be useful:
  ✓ To test hypothesis.
  ✓ To understand multiple environmental effects or interactions.
  ✓ For resources management at the filed-level.
  ✓ For resource management to assist policy decisions.
  ✓ As an educational tool to understand the effects of environment/management effects on crop functioning.
  ✓ For impact assessment of climate change on crop production systems across regions and nations.
“You cannot build peace on empty stomachs.”

John Boyd Orr
Nobel Peace Laureate
First FAO Director General

“You can’t eat the potential yield, but need to raise the actual by combating the stresses”

Norman E. Borlaug
Nobel Peace Laureate