Crop Responses to Abiotic Stresses: Tools and Methods

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Trends, Signs and Signatures from the Earth
Past, Present and Future World Population

![World Population Graph](image)

- **Y-axis**: Population in Billions
- **X-axis**: Year

The graph shows the historical and projected world population trends, highlighting significant increases, particularly in the 20th century.
Trends, Signs and Signatures from the Earth
Present and Future World Population Trends

Population, millions

Asia
2,367
China
1,437
India
1,628
Africa
1,941
Europe
728
Latin America
549
North America
326

-5% 42% 39%

56% 10% 50% 120%

2000
2050
Trends, Signs and Signatures from the Earth
Global Major Foods – Per Capita Consumption

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
Maize - Production and Yield – Selected Countries

Year | Maize yield, kg ha\(^{-1}\)
--- | ---
1960 | 0
1970 | 2000
1980 | 4000
1990 | 6000
2000 | 8000
2010 | 10000

USA: 156% @ 114 kg yr\(^{-1}\)
China: 335% @ 100 kg yr\(^{-1}\)
Brazil: 157% @ 47 kg yr\(^{-1}\)

Year | Maize production, MMt
--- | ---
1960 | 0
1970 | 50
1980 | 100
1990 | 150
2000 | 200
2010 | 250

USA: 226% @ 3.90 MMt yr\(^{-1}\)
China: 631% @ 2.77 MMt yr\(^{-1}\)
Brazil: 364% @ 0.73 MMt yr\(^{-1}\)

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\(^{-1}\)
Trends, Signs and Signatures from the Earth
Soybean - Production and Yield – Selected Countries

Year

Soybean yield, kg ha\(^{-1}\)
500 1000 1500 2000 2500 3000

USA: 69\% \@ 26 kg yr\(^{-1}\)
Brazil: 103\% \@ 37 kg yr\(^{-1}\)
China: 168\% \@ 26 kg yr\(^{-1}\)

Year

Soybean production, MMt
0 25 50 75 100

USA
Brazil
China

USA: 364\% \@ 1.35 MMt yr\(^{-1}\)
Brazil: \@ 0.99 MMt yr\(^{-1}\)
China: 183\% \@ 0.24 MMt yr\(^{-1}\)
<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 between 1985 and 2000**
Feeding 10 Billion Mouths

We must develop the capacity to feed 10 billion people within 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

- Efficiency of crop production in terms of:
  - Per unit of land area (yield/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
Tools Needed

Naturally-lit Plant Growth Chambers

System Tools – Models
SPAR and Environmental Manipulation
SPAR and Environmental Manipulation

- Temperature (10 to 40 °C).
- Carbon dioxide (200 to 1000 ppm).
- Solar radiation (no control, but sunlit).
- Water and wind (can be manipulated).
- Nutrients, N, P, K and others (can be manipulated).
- Others, UV-B radiation (can be manipulated from 0 to several times of ambient).
SPAR and Environmental Variables and Measurements

- Temperature (canopy, air and soil).
- Carbon dioxide.
- Solar radiation.
- UV-B radiation.
- Humidity.
- Soil moisture.
SPAR and Processes:

- **Canopy-level processes:**
  - Photosynthesis
  - Transpiration
  - Respiration
  - Light interception

- **Canopy development:**
  - Development or phenology
  - Growth rates of various organs
  - Organ abscission rates

- **Leaf-level processes:**
  - Photosynthesis and photo-chemistry
  - Physiological, biochemical and molecular parameters, etc.
About 250 per sq mm.
Typical Diurnal Photosynthesis and Light levels

![Graph showing diurnal photosynthesis and light levels]
Photosynthesis and Environment

Light-Response Curves

Photosynthesis, mg CO₂ m⁻² s⁻¹

PAR, µmol m⁻² s⁻¹

0 500 1000 1500 2000

720 ppm
360 ppm
Photosynthesis - Environment
Seasonal Trends

Days after Emergence
20 30 40 50 60 70 80 90 100 110 120 130 140 150 160

Photosynthesis, mg CO₂ m⁻² s⁻¹
0 1 2 3 4 5 6 7 8

PPFD 1200 µmole m⁻² s⁻¹

1995 ambient Temp.

720 CO₂
360 CO₂

Flower
Open Boll
Photosynthesis - Environment
Response to Water Deficits

Midday Leaf Water Potential, MPa

-4.0 -3.5 -3.0 -2.5 -2.0 -1.5 -1.0

Photosynthesis, mg CO₂ m⁻² s⁻¹

0 2 4 6 8 10

PPF, 1600 µmol m⁻² s⁻¹

700 µl l⁻¹ CO₂

350 µl l⁻¹ CO₂

Water-stressed
Well-watered
Crop Growth and Development
Crop Growth and Development

Cotton Vegetative Growth Response to Temperature

4-week old plants

20  25  30  35  40
Crop Growth and Development
Cotton Developmental Responses to Temperature

Events

Days between Events

Temperature, °C

Emergence to Square
Square to Flower
Flower to Open boll
### Cotton and High Temperature Injury

#### Pollen and Boll Parameters

<table>
<thead>
<tr>
<th>Growth condition</th>
<th>Flower</th>
<th>Pollen/anther</th>
<th>Boll retention, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>30/22 °C</td>
<td><img src="image1" alt="Flower Image" /></td>
<td><img src="image2" alt="Pollen Image" /></td>
<td>65</td>
</tr>
<tr>
<td></td>
<td></td>
<td>180-210</td>
<td></td>
</tr>
<tr>
<td>36/28 °C</td>
<td><img src="image3" alt="Flower Image" /></td>
<td><img src="image4" alt="Pollen Image" /></td>
<td>31</td>
</tr>
<tr>
<td></td>
<td></td>
<td>50-80</td>
<td></td>
</tr>
</tbody>
</table>
Crop Growth - Environment

Cotton Boll/Fruit Production Efficiency

Fruit Production Efficiency (g kg\(^{-1}\) Dry Weight)

Temperature, °C

Temperature, °C

24 26 28 30 32 34

700 µmol CO\(_2\) mol\(^{-1}\)

350 µmol CO\(_2\) mol\(^{-1}\)
Multiple Environmental Factors
Soybean Pollen Development – Sensitive Cultivar

- Optimum conditions: 30/22°C
- +T
- +UV-B
- +T+UV-B
Environmental Stresses, Genotypes and Parameters
Cotton, Soybean, Cowpeas, Peppers, Perennial Grasses

I. Stress Factors:
   Temperature, elevated CO2, UV-B radiation, either alone or in combination
   ✓ Pollen, fruit set, seed parameters, cell membrane thermostability, photosynthesis, fluorescence, etc.

Water deficits
   ✓ Photosynthesis and water-use efficiency parameters.
   ✓ Remote sensing parameters.

II. Statistical Tools:
   ✓ Combination of parameter, multivariate analysis (PCA, factor analysis, etc.)
Remote Sensing, Genotypes and their Response to Drought

**Cowpea Genotypes**
Questions?

For further information
www.spar.msstate.edu