Environmental Factors Temperature

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Environmental and Cultural Factors Limiting Potential Yields

- Atmospheric Carbon Dioxide
- Solar Radiation
- Temperature (Extremes)
- Water
- Wind
- Nutrients (N and K)
- Others, ozone etc.,
- Growth Regulators (PIX)

Temperature - Objectives

The objectives of this lecture are:

- To learn global, regional and local spatial and temporal/diurnal trends in temperature and ecological zones of plant adaptations/distributions.
- The influence of temperature on plants and ecosystems in general, and the cardinal temperatures of plant processes.
- The relationship between air and canopy temperature.
- Application of growing degree-day (GDD) concept.
- Temperature and remote sensing.

Environmental Factors - Temperature

- Temperature of the air, soil and canopy affects growth and developmental processes of plants.
- All crops have minimal, optimal and maximum temperature limits.
- These limits vary depending on the growth process or developmental event, even within a crop or species.
- Crop growth and development is more directly dictated by canopy temperature than air temperature.
- Root/soil temperature are also as critical as the air/canopy temperatures for crops because most crop’s roots have lower temperature optima and are less adapted to extremes and/or sudden fluctuations.

Environmental Factors - Temperature

- Temperatures below 6°C are lethal to most plants and prolonged exposure may kill or damage plants, probably due to dehydration, and temperatures above 10°C allow plants to grow.
- The upper lethal temperatures for most plants range from 45 to 50°C, depending on species, stage of growth and length of exposure.
- Temperatures of even 35 to 40°C can cause damage if they persist for longer periods.
- Generally, high temperatures are not as destructive to plants as low temperatures, provided the moisture supply is adequate to prevent wilting.

Environmental Factors

Temperature:

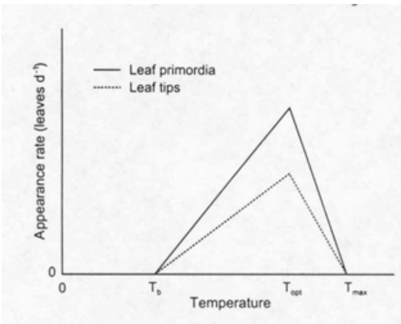
Strongly affects:

- -- Phenology
- -- Vegetative growth, LAI, LAD
- -- Fruit growth and retention
- -- Respiration
- -- Water-loss and water-use
- -- Leaf photosynthesis
- -- Uptake of nutrients and water
- -- Translocation of carbohydrates

Moderately affects:

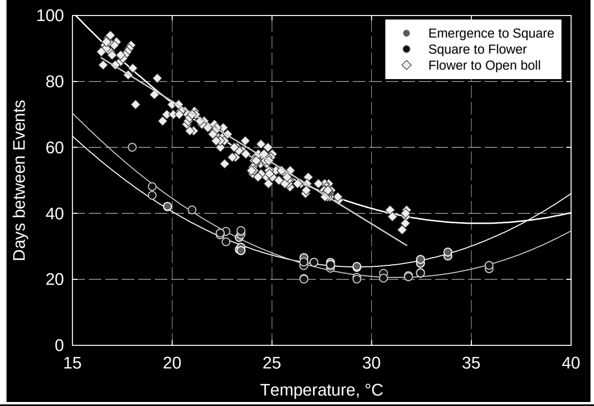
- -- Photosynthesis on a canopy basis

Temperature and Idealized Leaf Developmental Rates

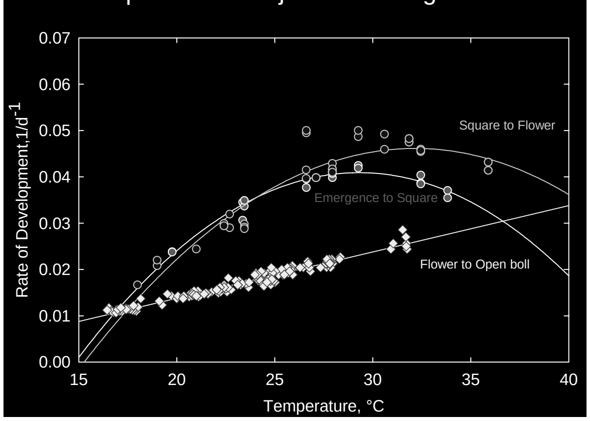


Kiniry et al., 1991

Temperature - Major Phenostages of Cotton

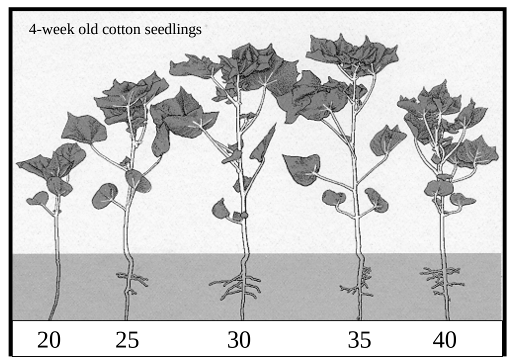


Temperature - Major Phenostages in Cotton



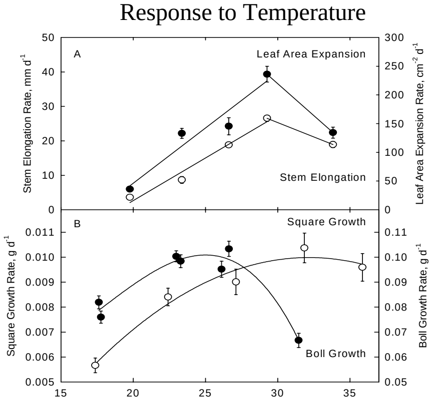
Crop Growth and Development - Environment

Response to Temperature



Crop Growth and Development - Environment

Response to Temperature



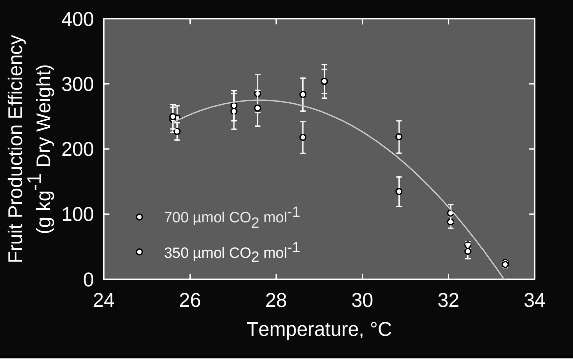
Projected Temperatures and Cotton Development

Treatment	Days to the Event		
	Square	Flower	Open Boll
1995 minus 2°C	33	65	144
1995 plus 0°C	26	51	101
1995 plus 2°C	24	48	94
1995 plus 5°C	21	42	77
1995 plus 7°C	19	39	No Fruit

No significant differences were observed between CO_2 levels

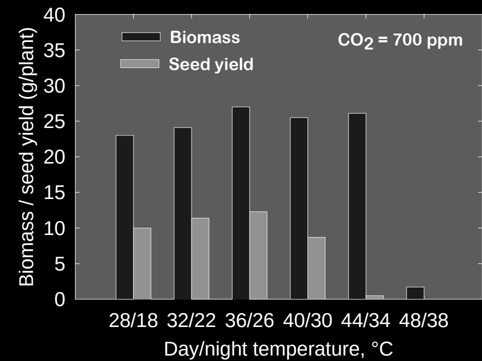
Crop Growth - Environment

Response to temperature - Cotton fruit production efficiency



Crop Growth and Development - Environment

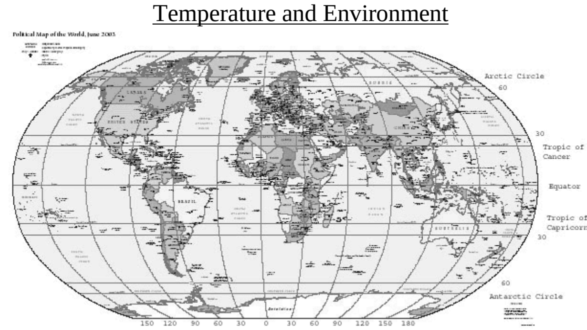
Response to temperature - Soybean biomass and seed yield



Mean temperatures of the northern and southern hemispheres

Season	Hemisphere	
	Northern	Southern
	°C	
Summer	22.4	17.1
Winter	8.1	9.7

Temperature and Environment



- Air temperature varies from place to place and over time at a given location.
- Temperatures generally decrease poleward from the equator; showing latitude influencing the insulation and thus temperatures.

Temperature and Spatial Trends Across the World

Fairbanks, Alaska – Boreal

Spokane, WA – Temperate

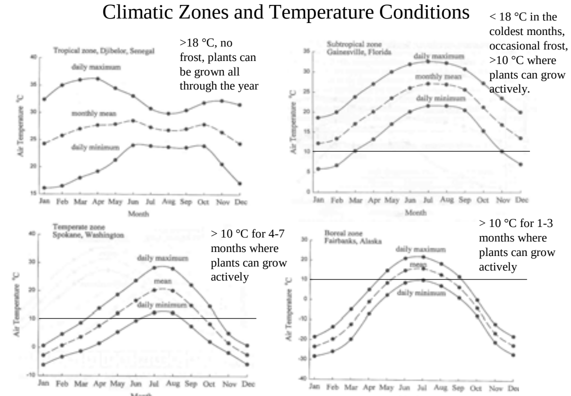
Gainesville, FL – Sub-tropical

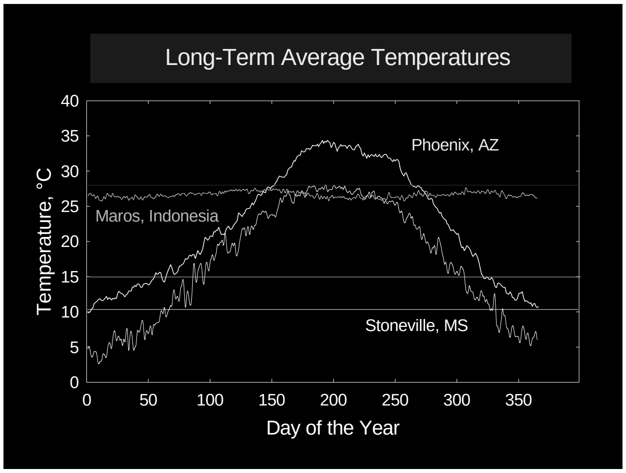
Senegal, Africa – Tropical

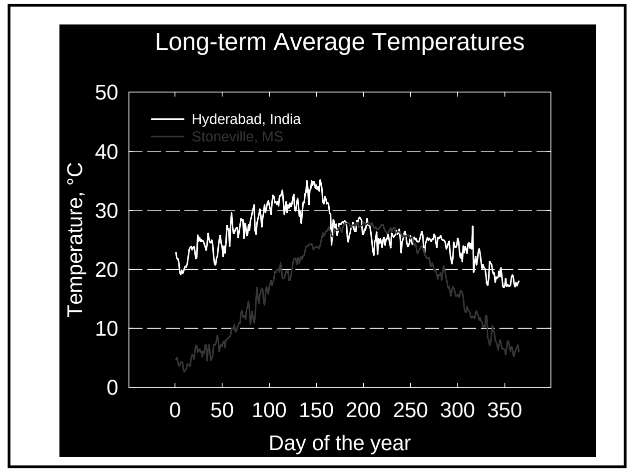
Hyderabad, India – Semiarid

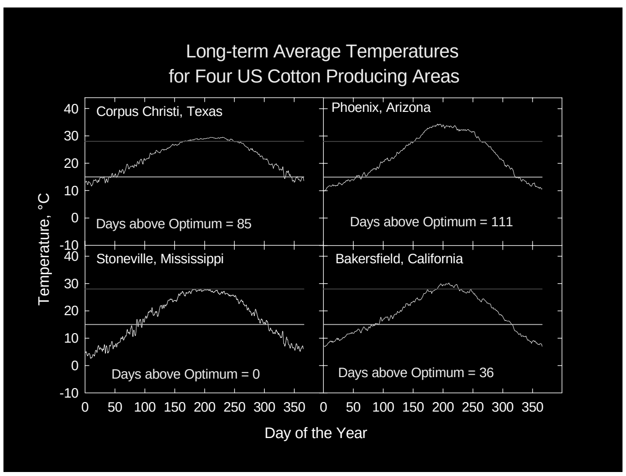
Maros, Indonesia – Equatorial

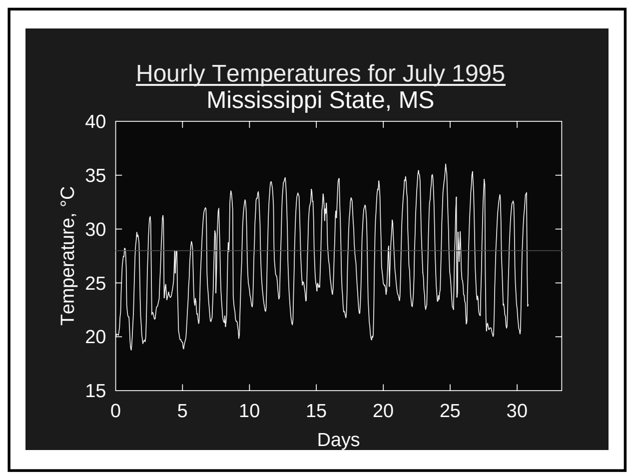
Climatic Zones and Temperature Conditions

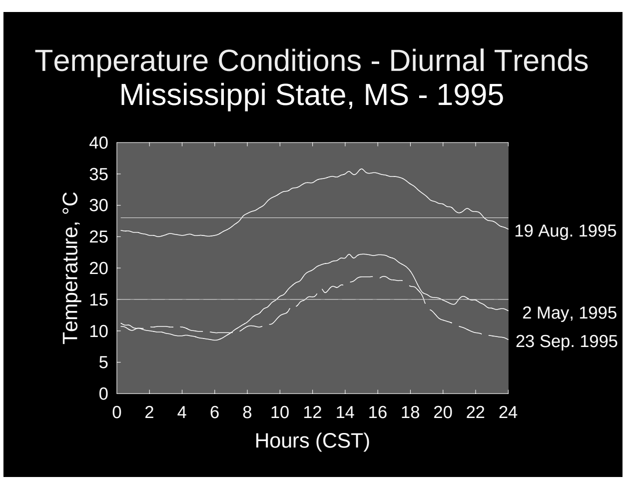


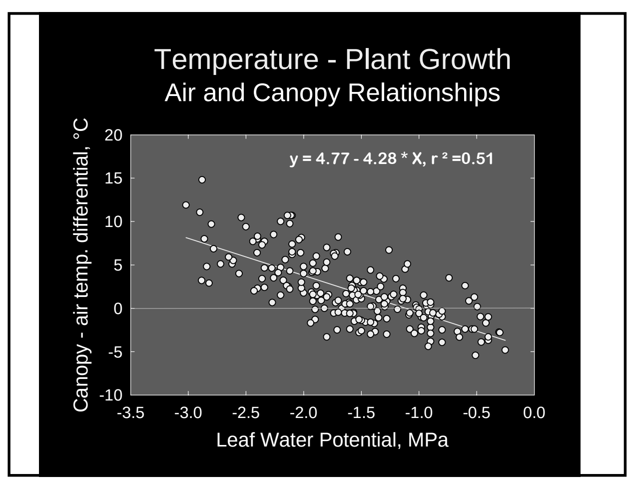

Long-Term Average Temperatures
Temperature, °C
Day of the Year
Phoenix, AZ
Maros, Indonesia
Stoneville, MS


Long-term Average Temperatures
Hyderabad, India
Stoneville, MS
Temperature, °C
Day of the year


Long-term Average Temperatures
for Four US Cotton Producing Areas
Corpus Christi, Texas
Days above Optimum = 85
Phoenix, Arizona
Days above Optimum = 111
Stoneville, Mississippi
Days above Optimum = 0
Bakersfield, California
Days above Optimum = 36
Temperature, °C
Day of the Year


Hourly Temperatures for July 1995
Mississippi State, MS
Temperature, °C
Days


Temperature Conditions - Diurnal Trends
Mississippi State, MS - 1995
Temperature, °C
19 Aug. 1995
2 May, 1995
23 Sep. 1995
Hours (CST)


Temperature - Plant Growth
Air and Canopy Relationships
y = 4.77 - 4.28 * X, r ² =0.51
Canopy - air temp. differential, °C
Leaf Water Potential, MPa

Predicted Annual Temperature Increase in GCMs for Doubled CO_2 Scenario

(Adams et al., 1990)

Region	GISS	GFDL
	°C	
Southeast	3.5	4.9
Delta	5.3	4.4
Northern Plains	4.7	5.9
Southern Plains	4.4	4.5
Mountain	4.9	5.3
Pacific	4.7	4.7

Climate Change and Variability

Climate change may exacerbate the frequency of extreme events such as brief spells of:

- High and low temperature episodes
- Torrential storms – Hurricanes, tornados, blizzards etc.,
- Droughts
- Floods

Summary

- Air temperature varies from place to place and over time at a given location.
- Temperatures generally decrease poleward from the equator; showing latitude influencing the insulation and thus temperatures.
- This general equator-to-pole temperature decline is modified by location of land and water surfaces and seasonal changes in Sun's position relative to these surfaces.
- The annual range or seasonality in temperature is less at coastal locations and equatorial regions than for inland or temperate locations.
- Canopy temperatures may play a direct role in dictating canopy growth and development and thus crop yield.

Summary

- The active temperature range for plants is generally between 5 to 40 C; however survival temperatures are greater.
- Individual species usually have a rather narrow range in which they can function, however across species the range is extended considerably.
- For example, snow algae as well as snow mold infests the snow covered twigs of conifers, and on the other hand, some thermophillus bacteria and blue green algae survive in very high temperatures in the water of geysers.
- The range of the cardinal temperatures, the base and maximum, and the range and magnitude of the optimum, also vary among species.

Summary

- Temperature also varies based on altitude, approximately 3°F for every 1000 ft. increase in altitude. This change in temperature gradient will affect distribution of natural species of plants as well as crop production possibilities.
- Winter annuals and biennials as well as the buds of some woody species (e.g. Peach) require a cold season in order to flower normally; they have a chilling requirement (temperatures below 3°C to 13°C, ideally between 3 to 15°C for weeks). This process is called vernalization.
- If this process is too short or interrupted by warming above 15°C, then the effect is cancelled.
- If the climate in the future is more variable, then we can expect seasonal fuzziness and variation in extreme conditions. And this phenomenon may pose a serious problem for certain crops, particularly for those crops that require vernalization.

Summary

- Heat and cold stress may also vary from species to species and plants will be affected by these factors.
- Plant are also very sensitive to temperatures below the freezing (0°C), and chilling (5 to 0°C) temperature conditions.

How can we use temperatures in a crop production environment?

- Determining the length of a growing season of crops at a given location.
- Temperature summation is normally used to drive or to derive growth and development of crops.
- Canopy minus air temperature indices are being used in irrigation management and scheduling in many areas.

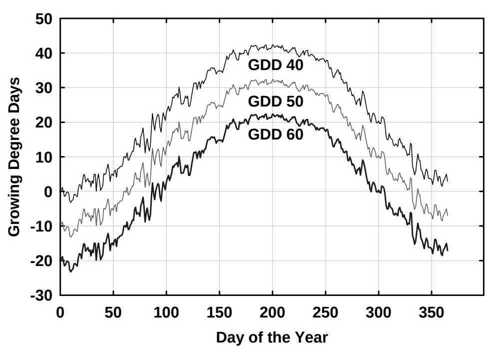
How can we use temperatures in a crop production environment?

- Determining the length of a growing season for crops at a given location.

The positive summation of temperature above a certain base has been proposed to measure thermal efficiency. This system is called: growing degree days (GDD), heat unit (HU) accumulation, thermal time (TT) accumulation etc.,

If the maximum and minimum temperatures for a given day are 30 and 20°C, respectively, then GDD for that day will be: [(30 + 20)/2] – base temperature (12°C) = 13 GDDs

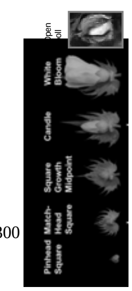
Long-term (42-year) average daily growing degree days at Stoneville, MS



How can we use temperatures in a crop production environment?

For cotton: The GDD are as follows for various developmental events based on a 60 °F (15°C) base temperature.

	Average	Low	High	DD-60's
	----------- days -------------			
Sowing to emergence:	7	4	10	50-60
Emergence to square:	32	27	38	425-475
Square to white bloom:	23	20	25	300-350
Sowing to white bloom:	62	51	73	775-850
White bloom to open boll:	55	45	66	750
Sowing to mature crop:				2,150-2,300



Days from white bloom to peak bloom: 30 (25-35)

Days from white bloom to 60% boll opening: 30 (25-35)

Days to produce a normal crop: 150 (130-170)

How can we use temperatures in a crop production environment?

- Temperature summation is normally used to drive or to derive growth and development of crops.

For cotton:

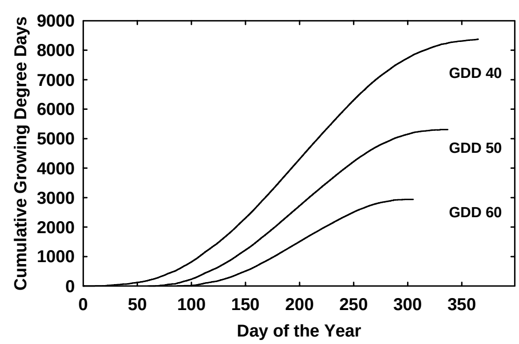
The GDD for various developmental events are as follows.

Adding a leaf on the mainstem = 40 from a 12°C base temperature.

Varietal variation from sowing to square:

Early season	330
mid-season	390
Late-season	450

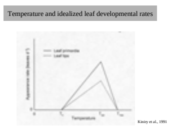
Long-term (42-year) average cumulative growing degree days at Stoneville, MS

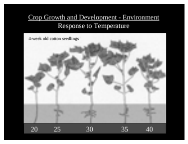


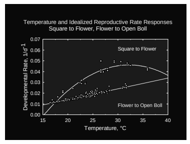
How to use temperatures in a crop production environment?

The GDD concept – Applicability or limitations:

- ➢ Assumes the growth and development as a linear function of temperature.



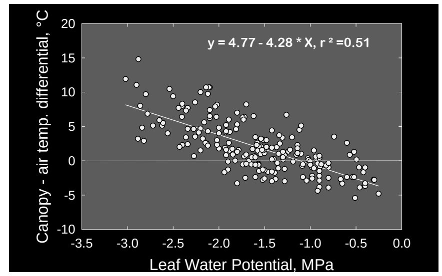




- ➢ The GDD concept and it's use:
  - ✓ No consideration for stresses, for example in dry or nutrient deficit environments, the rate of development will be delayed or hastened depending upon the stress condition.

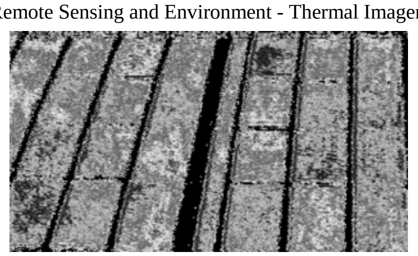
How can we use temperatures in a crop production environment?

- ➢ Canopy minus air temperature indices are being used in irrigation management and scheduling in many areas.



How can we use temperatures in a crop production environment?

Remote Sensing and Environment - Thermal Imagery



Thermal image of a cotton canopy that was part of a water and nitrogen study in Arizona. Blues and greens represent lower temperatures than yellow and orange. The image was acquired with a thermal scanner on board a helicopter. Most of the blue rectangles (plots) in the image correspond to high water treatments.

Reading/Reference Material

1. Ritchie, G.L., C.W. Bednarz, P.H. Jost, and S.M. Brown. 2004. Cotton Growth and Development. Bulletin 1252, , pp 16. Cooperative Extension Service, The University of Georgia College of Agricultural and Environmental Sciences. Athens, GA.

2. University of CA Cotton Web Site (http://cottoninfo.ucdavis.edu) 1, (July, 2002) - COTTON GUIDELINES section.

3. Hall, A.E. 2001. Crop Responses to Environment, Chapter 6. Crop developmental responses to temperature, pp. 83-95, CRS Press (Read this).

4. Hall, A.E. 2001. Crop Responses to Environment , Chapter 5. Crop physiological responses to temperature and climatic zones, pp.59-82, CRS Press (Read this as well).

5. Seidel1, D.J., Q. Fu, W.J. Randel, T.J. Reichler. 2007. Widening of the tropical belt in a changing climate. Nature 445, 528–532.