

# 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 (water as well) and canopy affects growth and developmental processes of plants.
- All crops (plants) have minimum, optimum and maximum temperature limits known as cardinal temperatures.
- These limits vary depending on the growth process or developmental event, even within a crop or species.
- Crop growth and development are 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  $6^{\circ}\text{C}$  are lethal to most plants and prolonged exposure may kill or damage plants, probably due to dehydration, and temperatures above  $10^{\circ}\text{C}$  allow plants to grow.
- The upper lethal temperatures for most plants range from  $45$  to  $50^{\circ}\text{C}$ , depending on species, stage of growth and length of exposure.
- Temperatures of even  $35$  to  $40^{\circ}\text{C}$  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:**

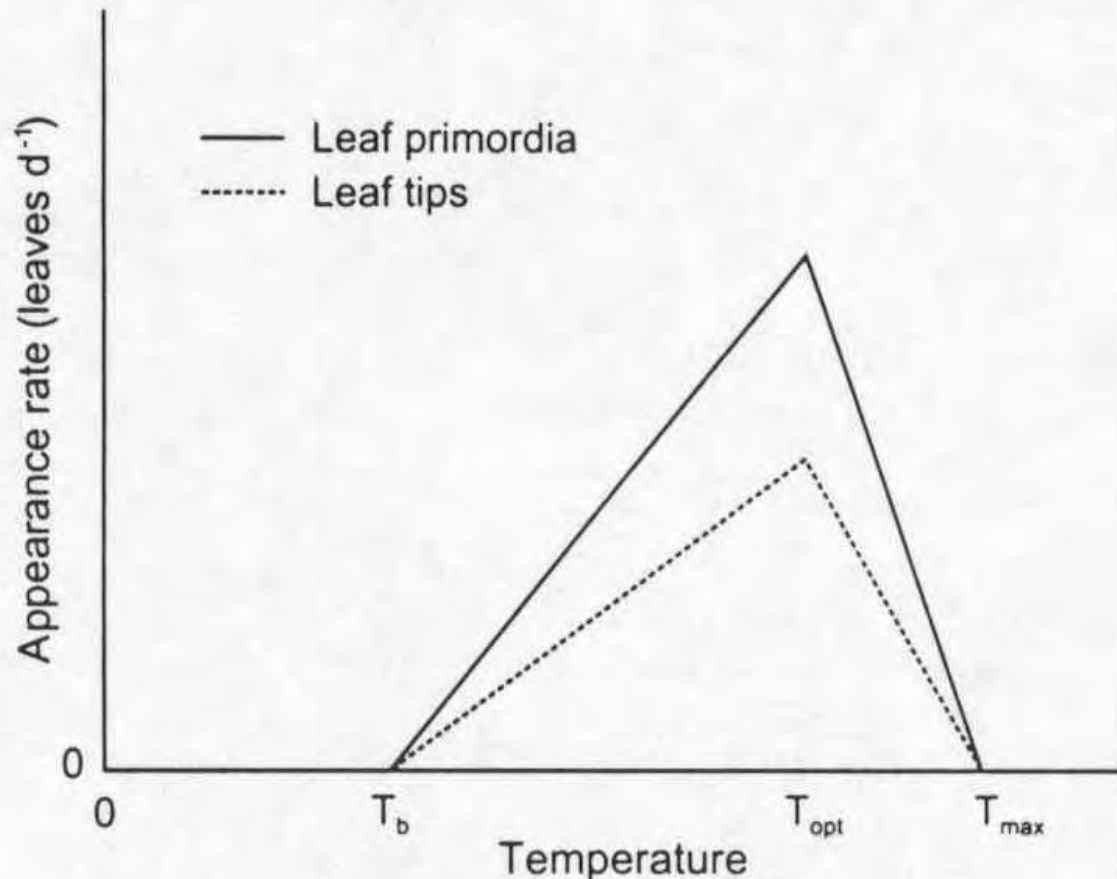
- Phenology
- Vegetative growth, LAI, LAD
- Fruit growth and retention
- Respiration
- Water-loss and water-use
- Leaf photosynthesis
- Uptake of nutrients and water
- Translocation of carbohydrates

**Moderately affects:**

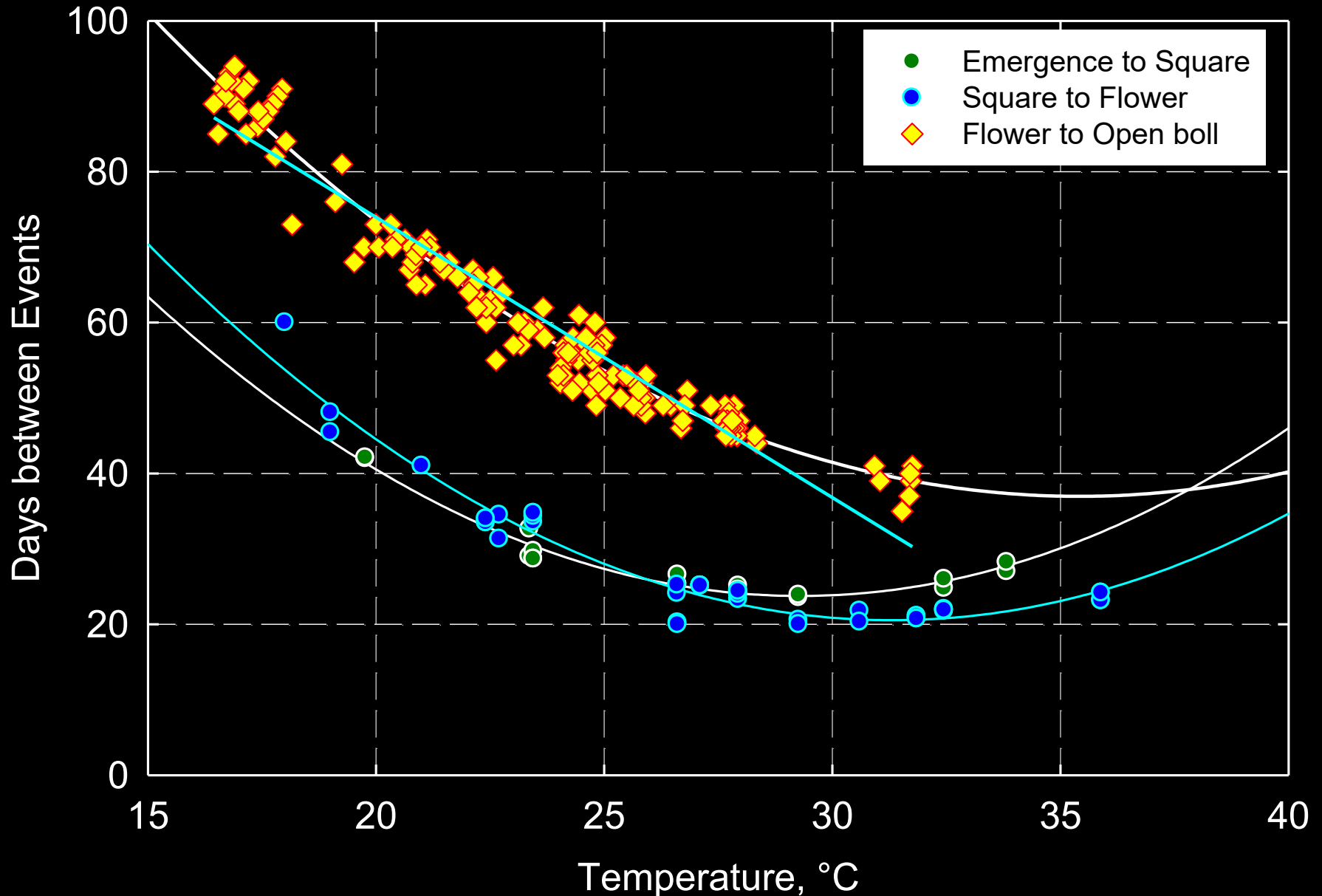
- Photosynthesis on a canopy basis

# Temperature and Idealized Leaf Developmental Rates

The cardinal temperatures are **T<sub>b</sub> = Base or minimum** (growth and development are zero), **T<sub>opt</sub> = the optimum** (growth and development are maximum), and **T<sub>max</sub> = the maximum** (growth and development are zero again as in T<sub>base</sub>)

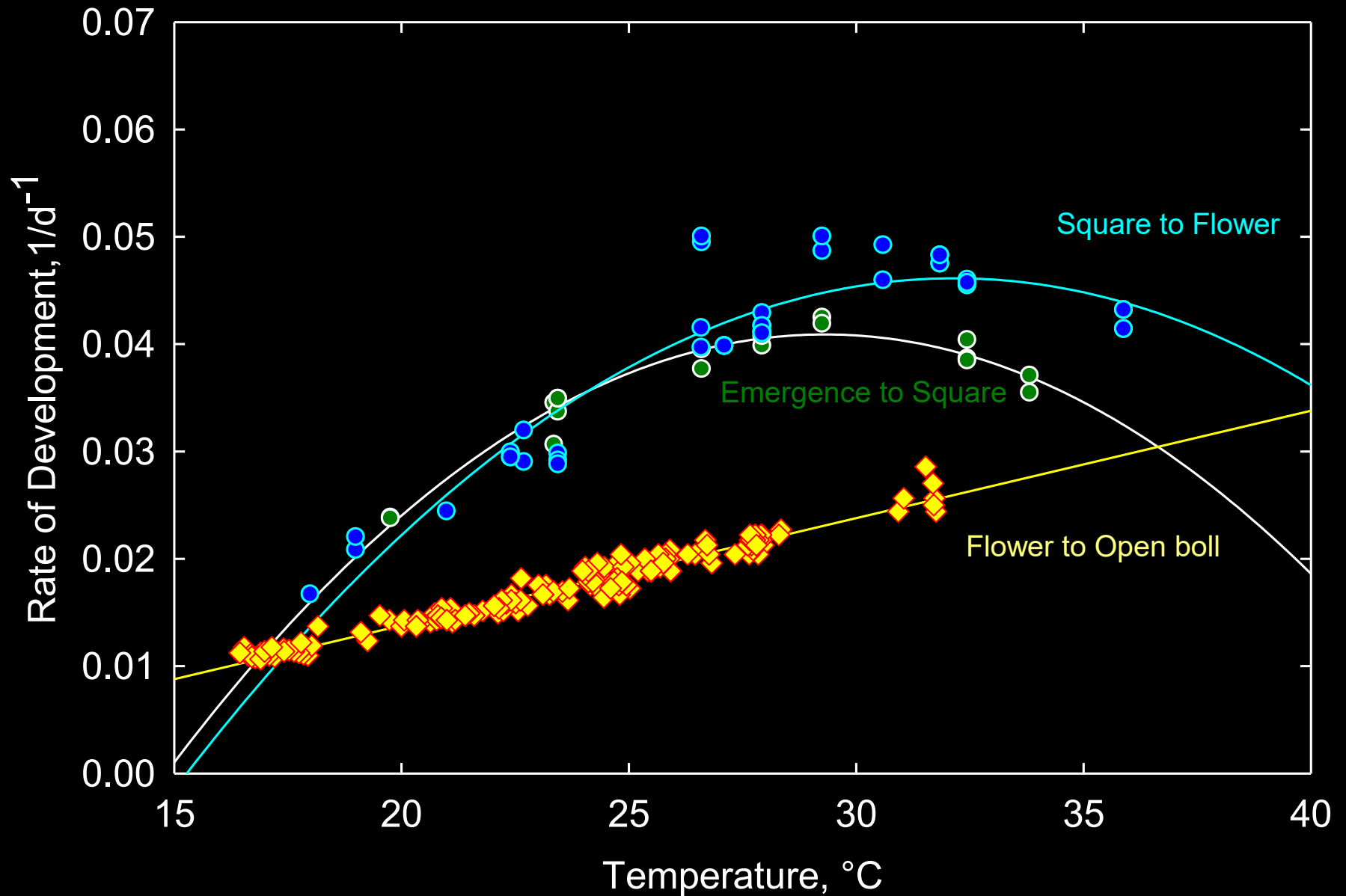


# Temperature - Major Phenostages of Cotton





# Temperature - Major Phenostages in Cotton



# Crop Growth and Development - Environment

## Response to Temperature

4-week old cotton seedlings



20/12

25/12

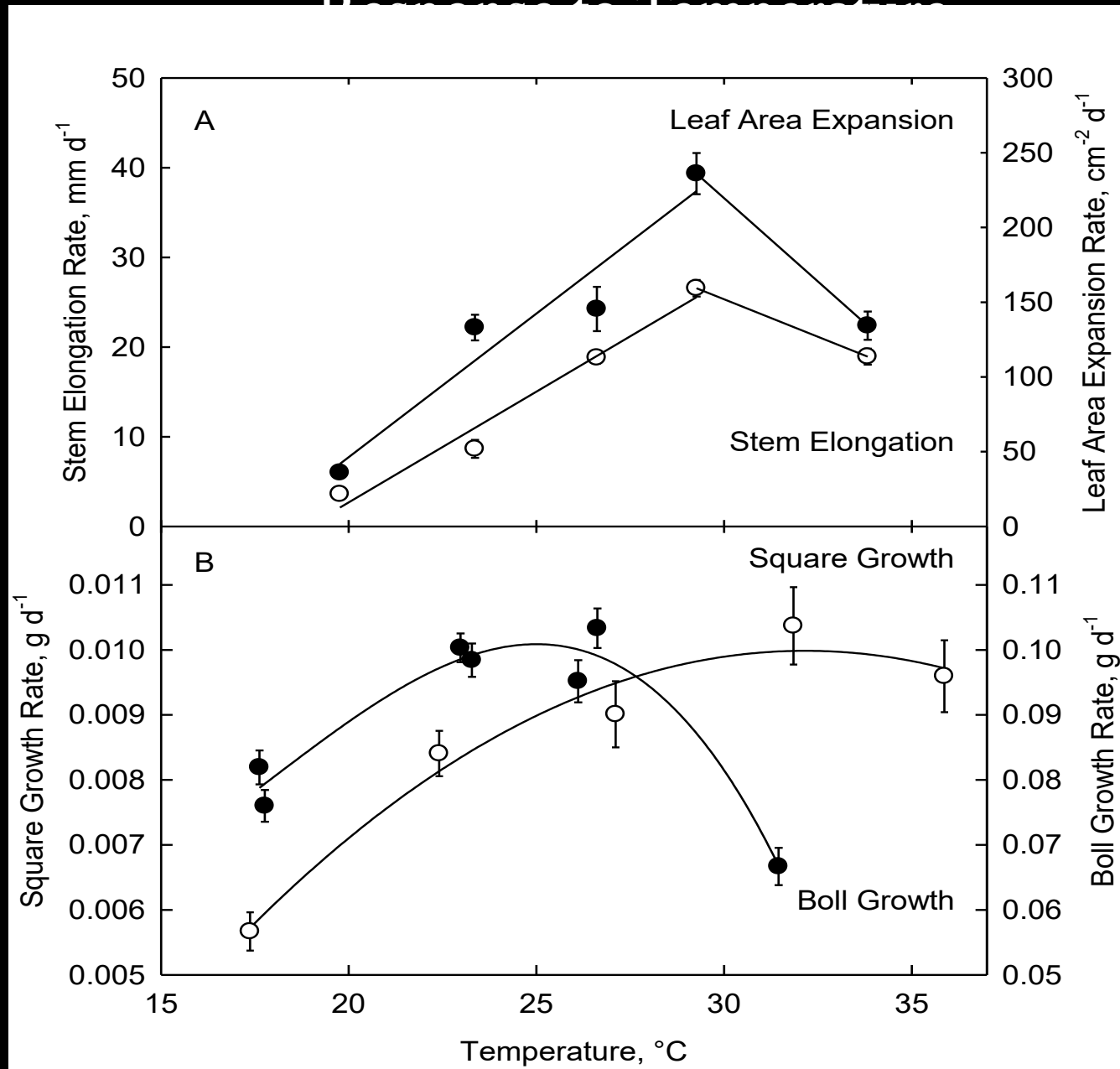
30/22

35/27

40/32

Day/Night Temperature, °C

# Crop Growth and Development - Environment



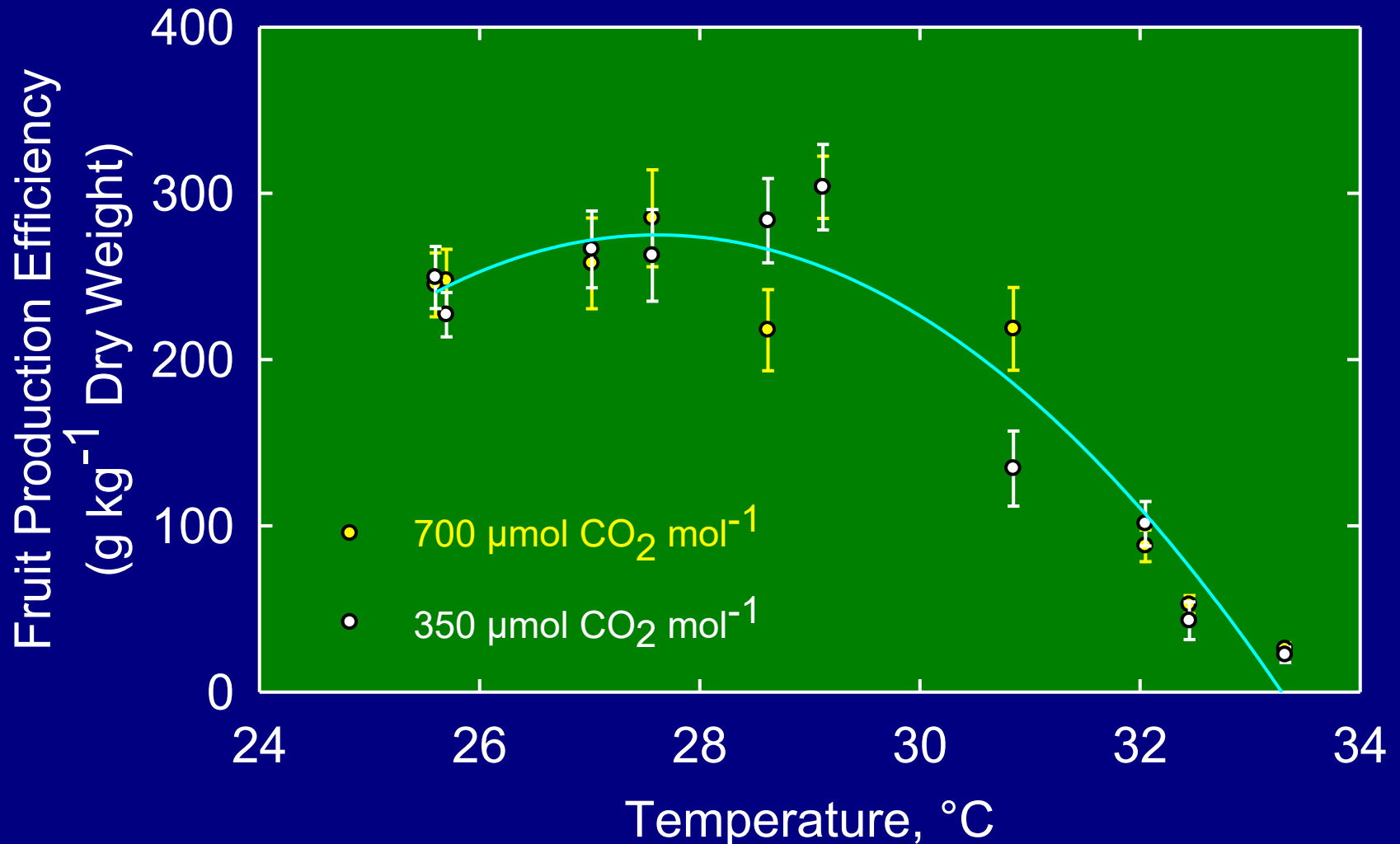
# Projected Temperatures and Cotton Development

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<sub>2</sub> levels

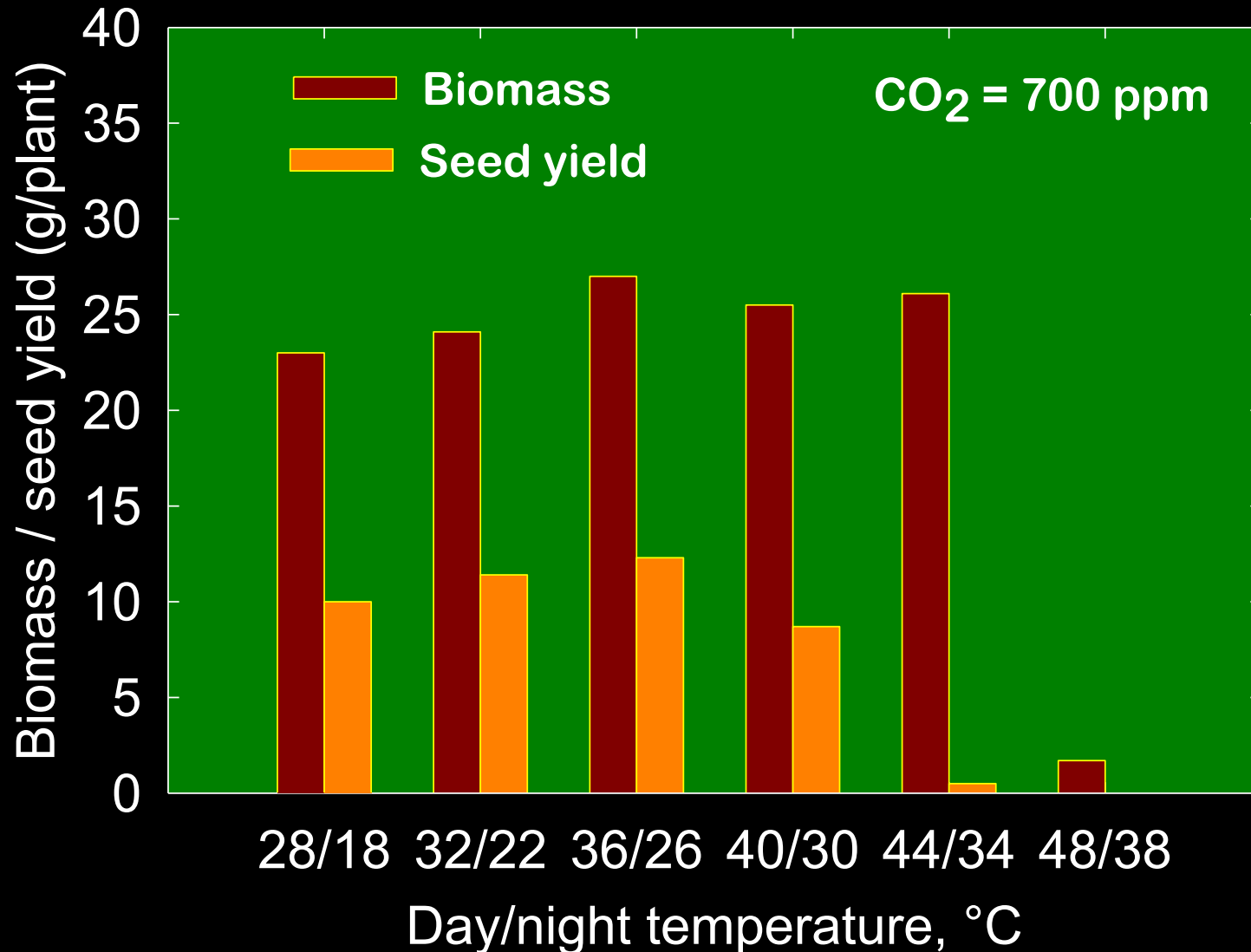
# Crop Growth - Environment

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

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Season

Hemisphere

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Northern Southern

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°C

Summer

22.4

17.1

Winter

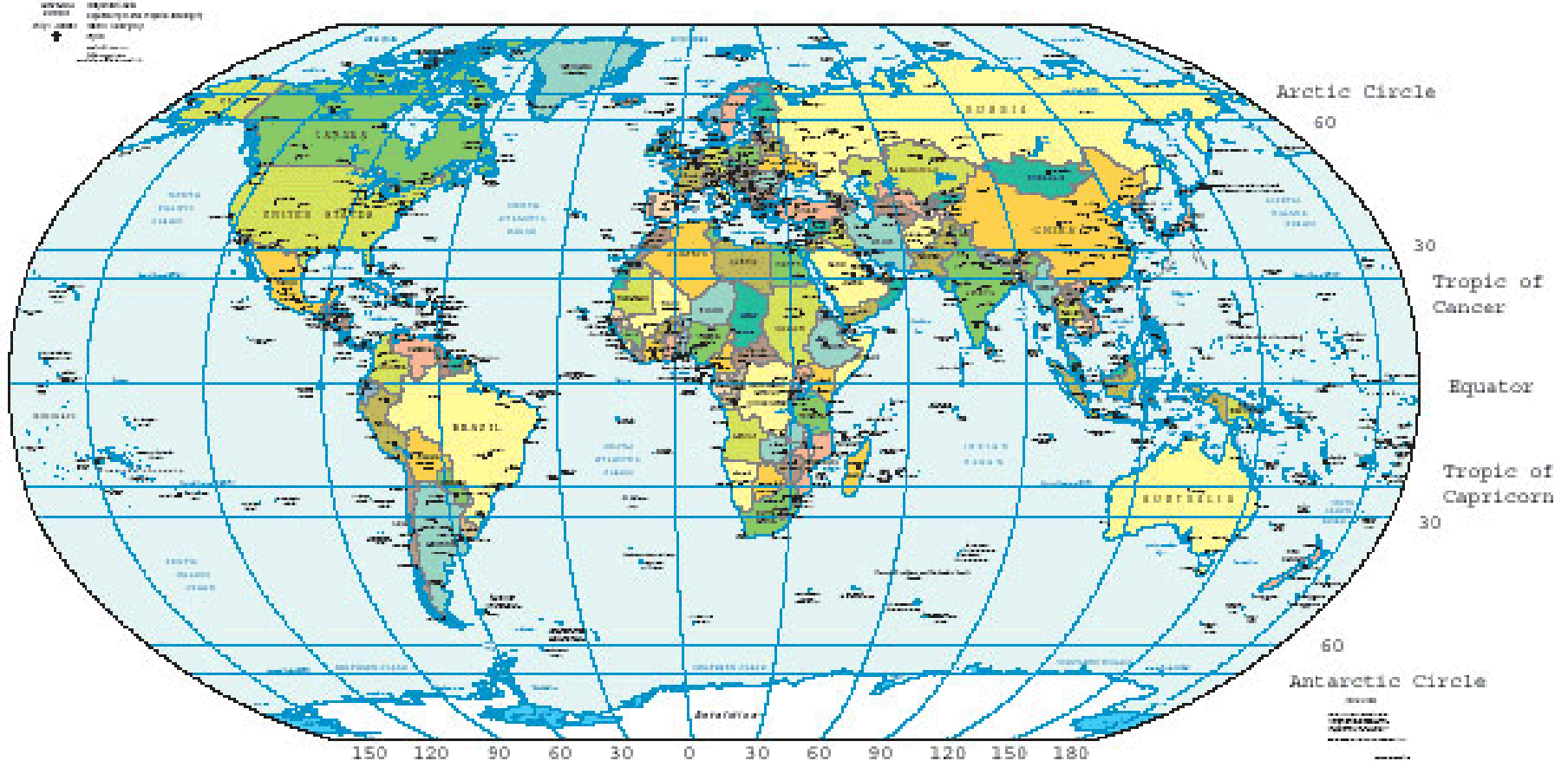
8.1

9.7

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# Temperature and Environment

Political Map of the World, June 2003



- 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

## Koppen Climate Classification System

Political Map of the World



Fairbanks, Alaska – Boreal

Spokane, WA – Temperate

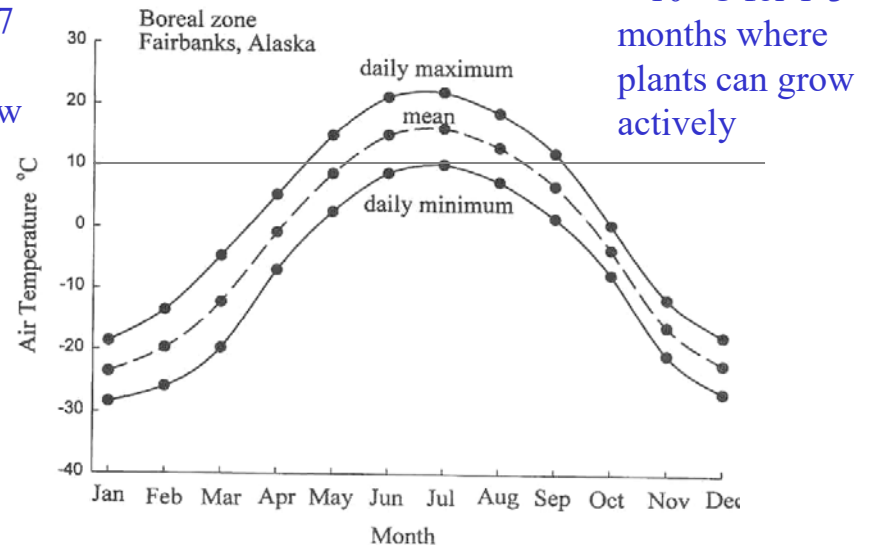
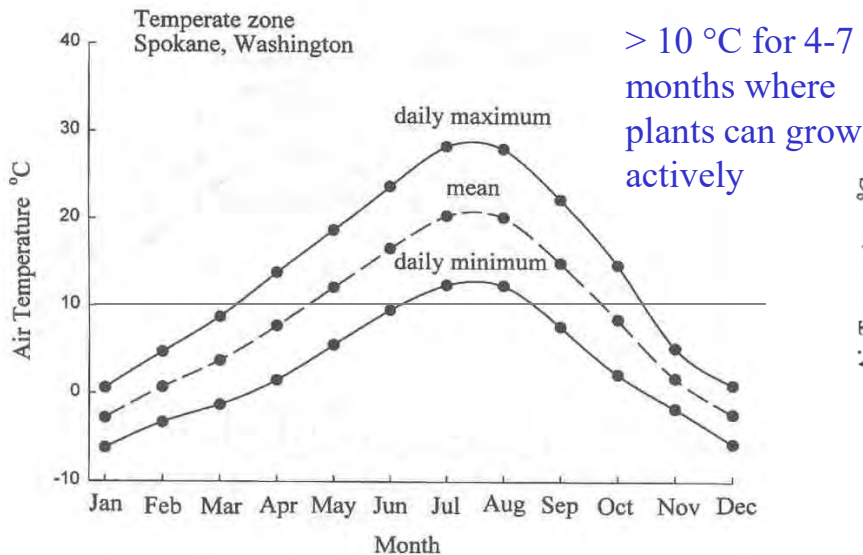
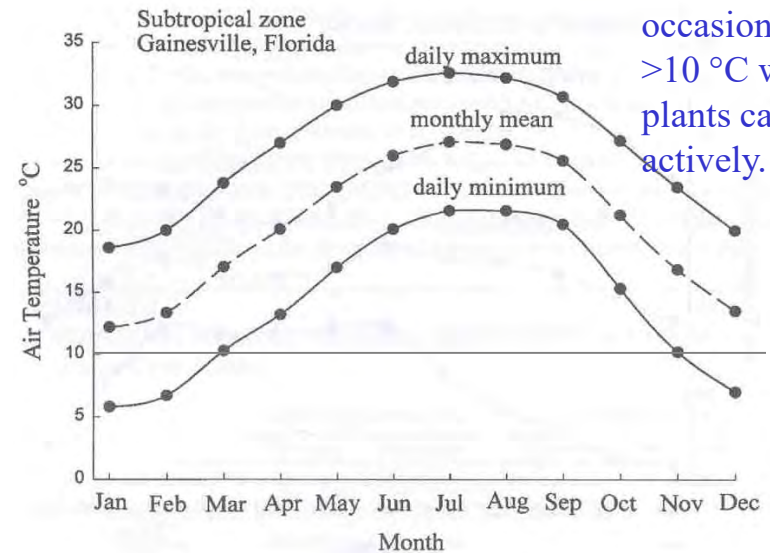
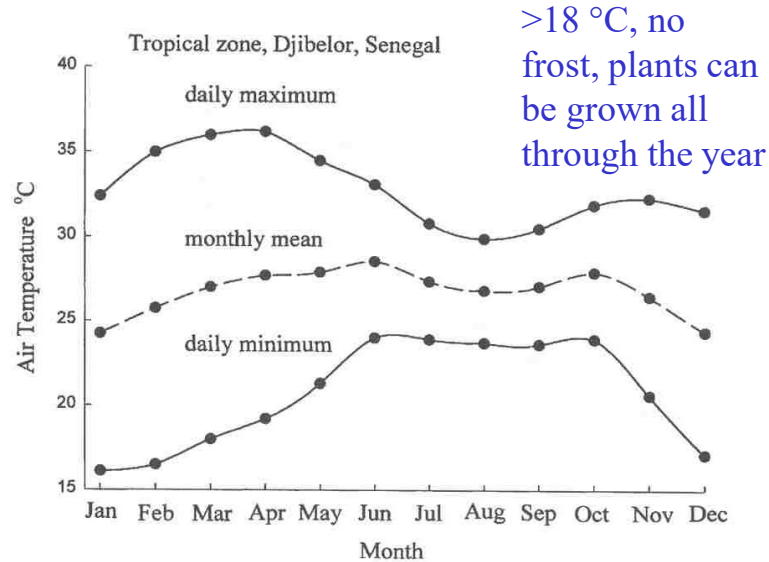
Gainesville, FL – Sub-tropical

Senegal, Africa – Tropical

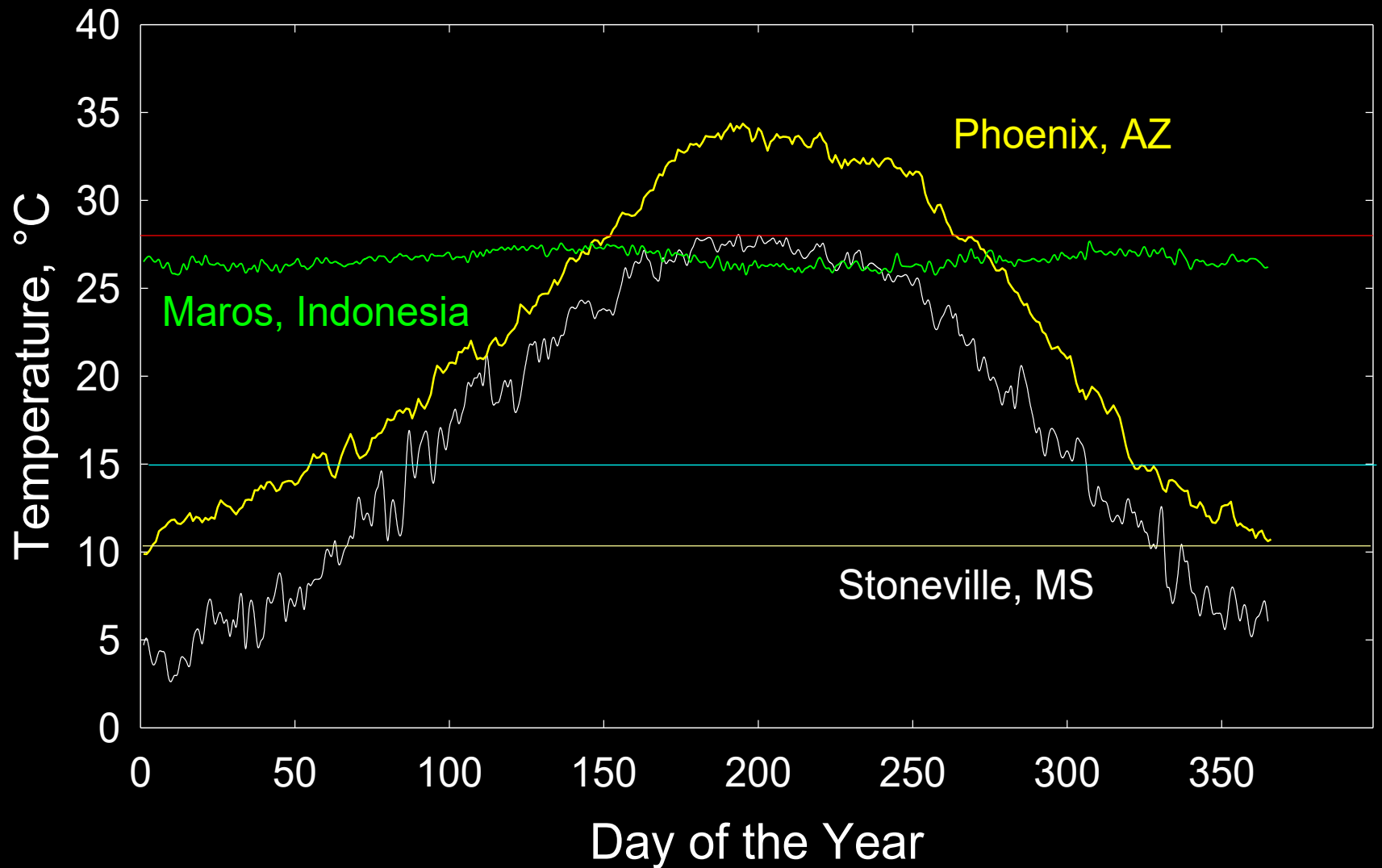
Hyderabad, India – Semiarid

Maros, Indonesia – Equatorial

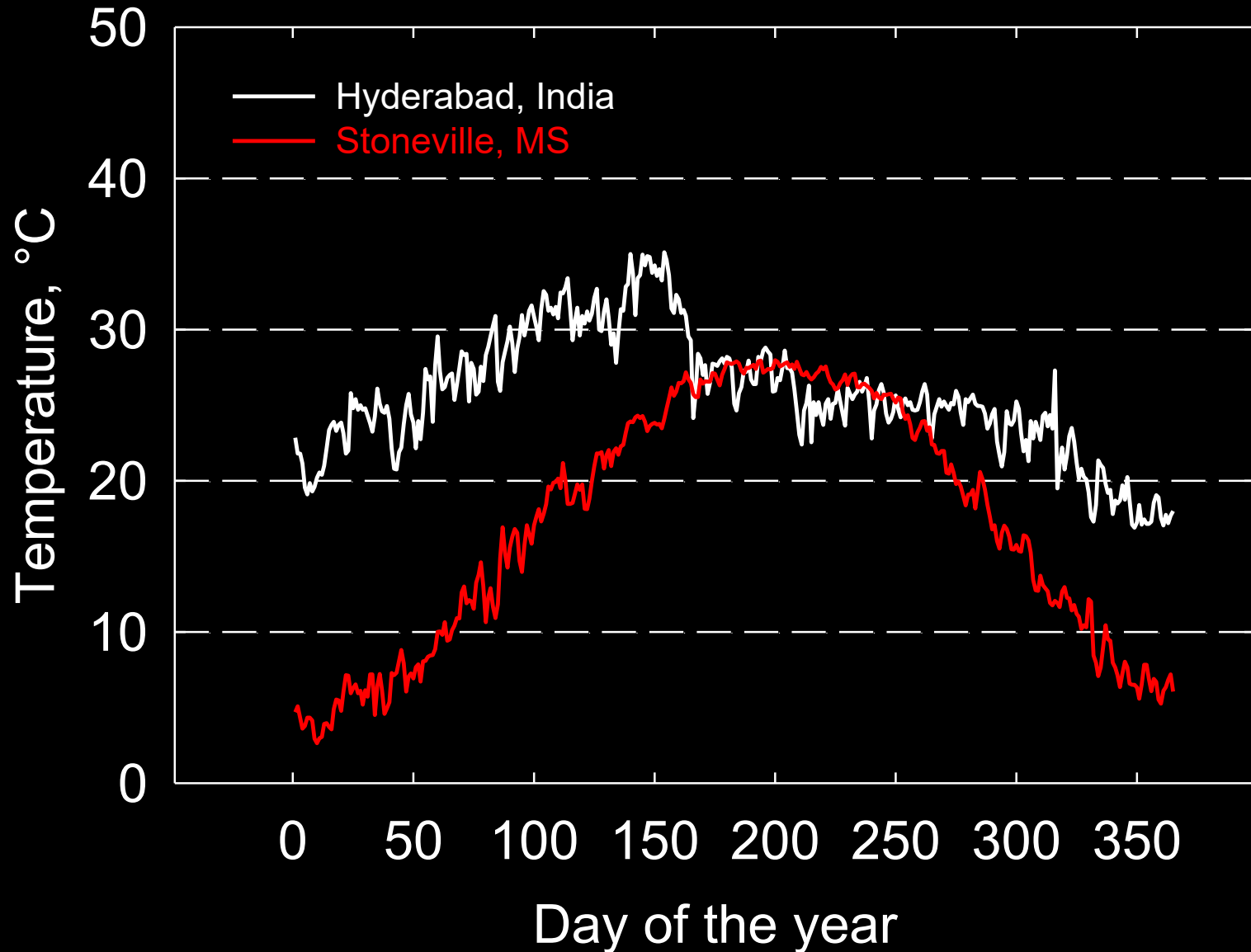
# Climatic Zones and Temperature Conditions



# Long-Term Average Temperatures

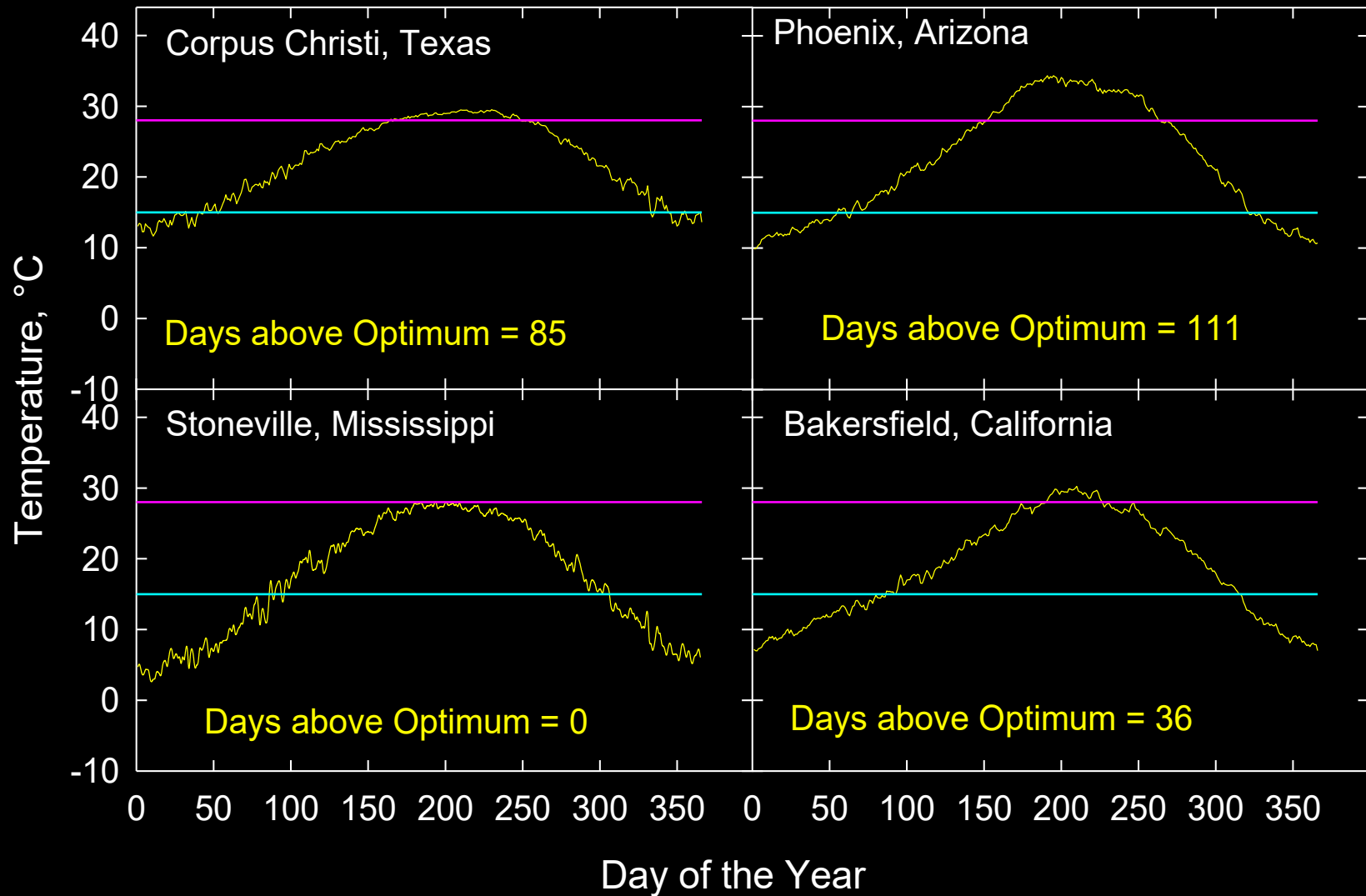


# Long-term Average Temperatures



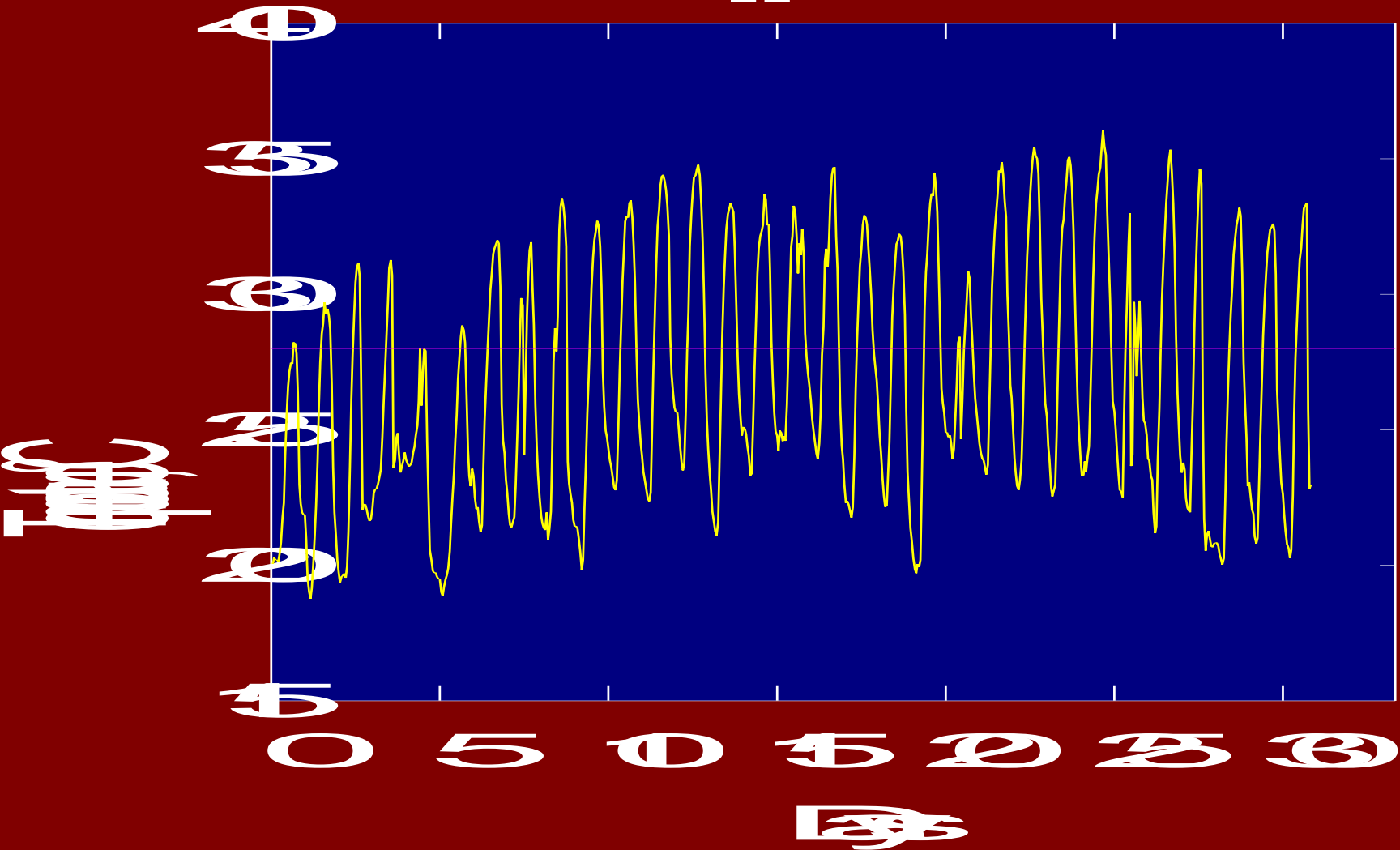


# Long-term Average Temperatures for Four US Cotton Producing Areas



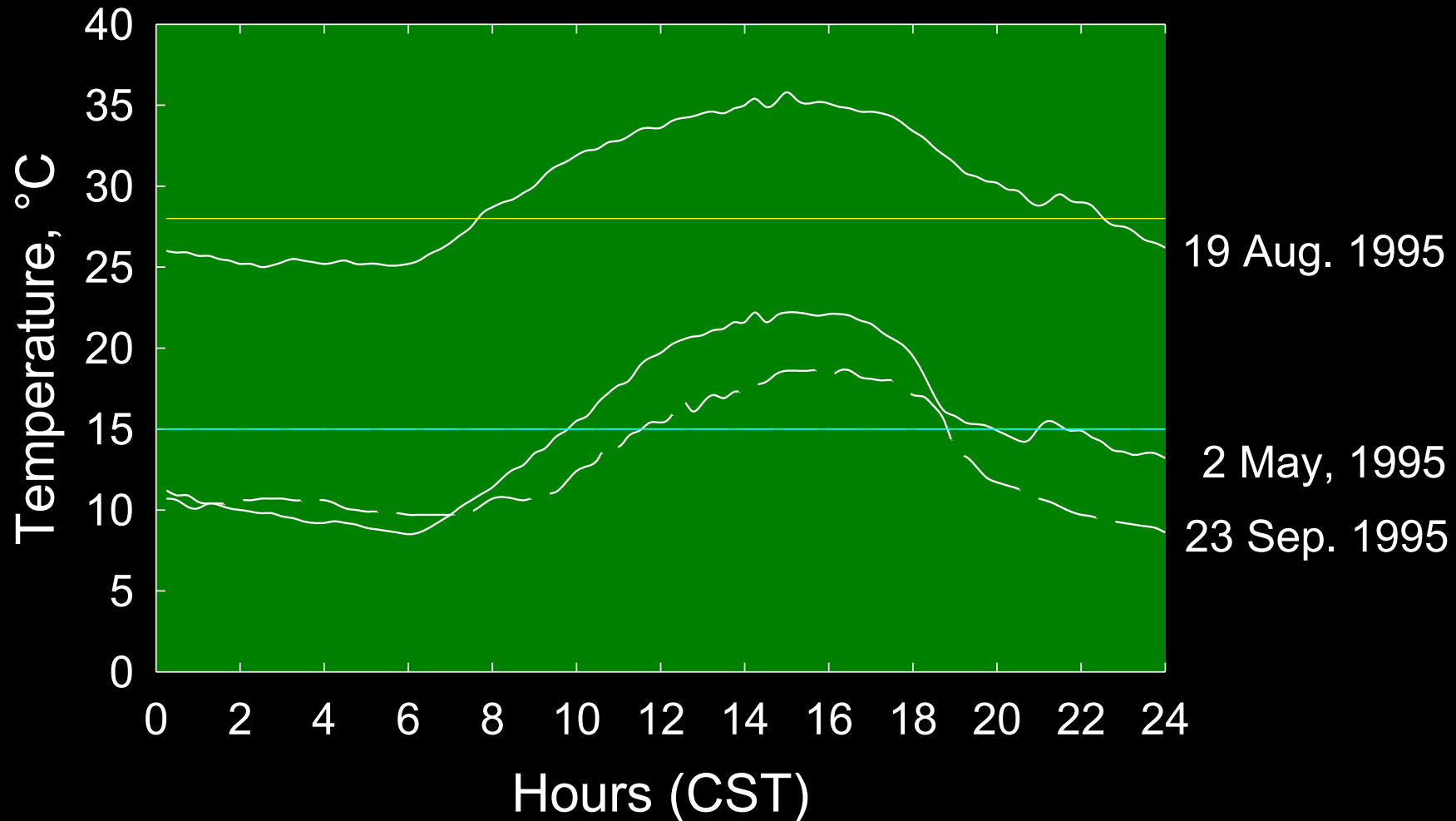
# 10th September 1995

## Neap tide



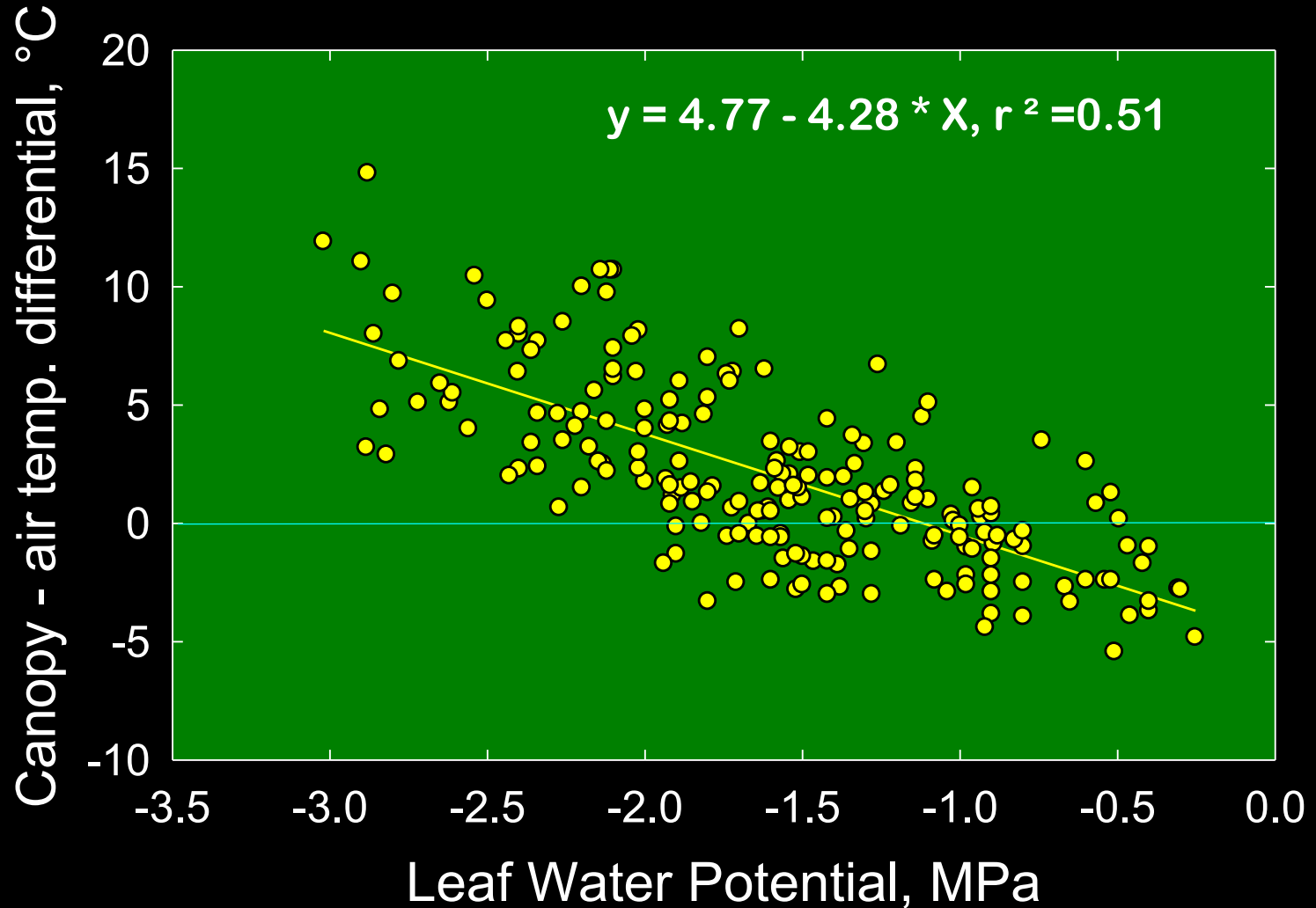
# Temperature Conditions - Diurnal Trends

## Mississippi State, MS - 1995



# Temperature - Plant Growth

## Air and Canopy Relationships



# Relative humidity in different areas

(~~Table 9~~)

Region	ES ED	
	°C	
South	35	49
East	53	44
North-east	47	59
South-east	44	45
North	49	53
West	47	47

# 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 of temperature 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 thermophilus 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 ( $0^{\circ}\text{C}$  ), and chilling (5 to  $0^{\circ}\text{C}$ ) 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?

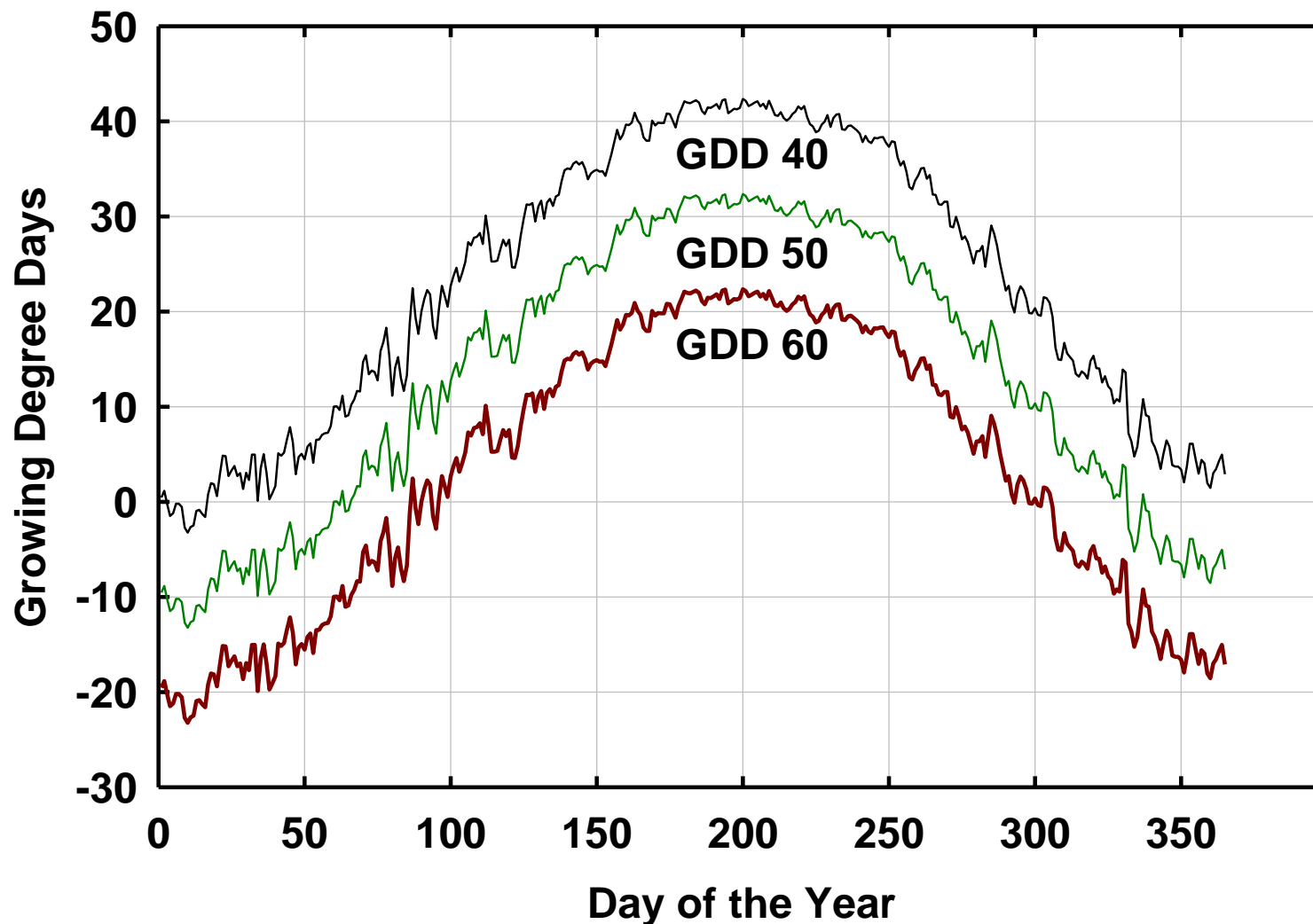
- Determining the length of a growing season for crops at a given location.

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:  $[(30 + 20)/2] - \text{base temperature } (12^{\circ}\text{C}) = 13 \text{ GDDs}$



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



# How can we use temperatures in a crop production environment?

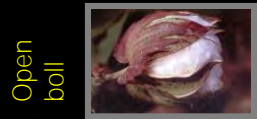
For cotton: The GDD are as follows for various developmental events based on a 60 °F (15°C) base temperature.

	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 peak 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:

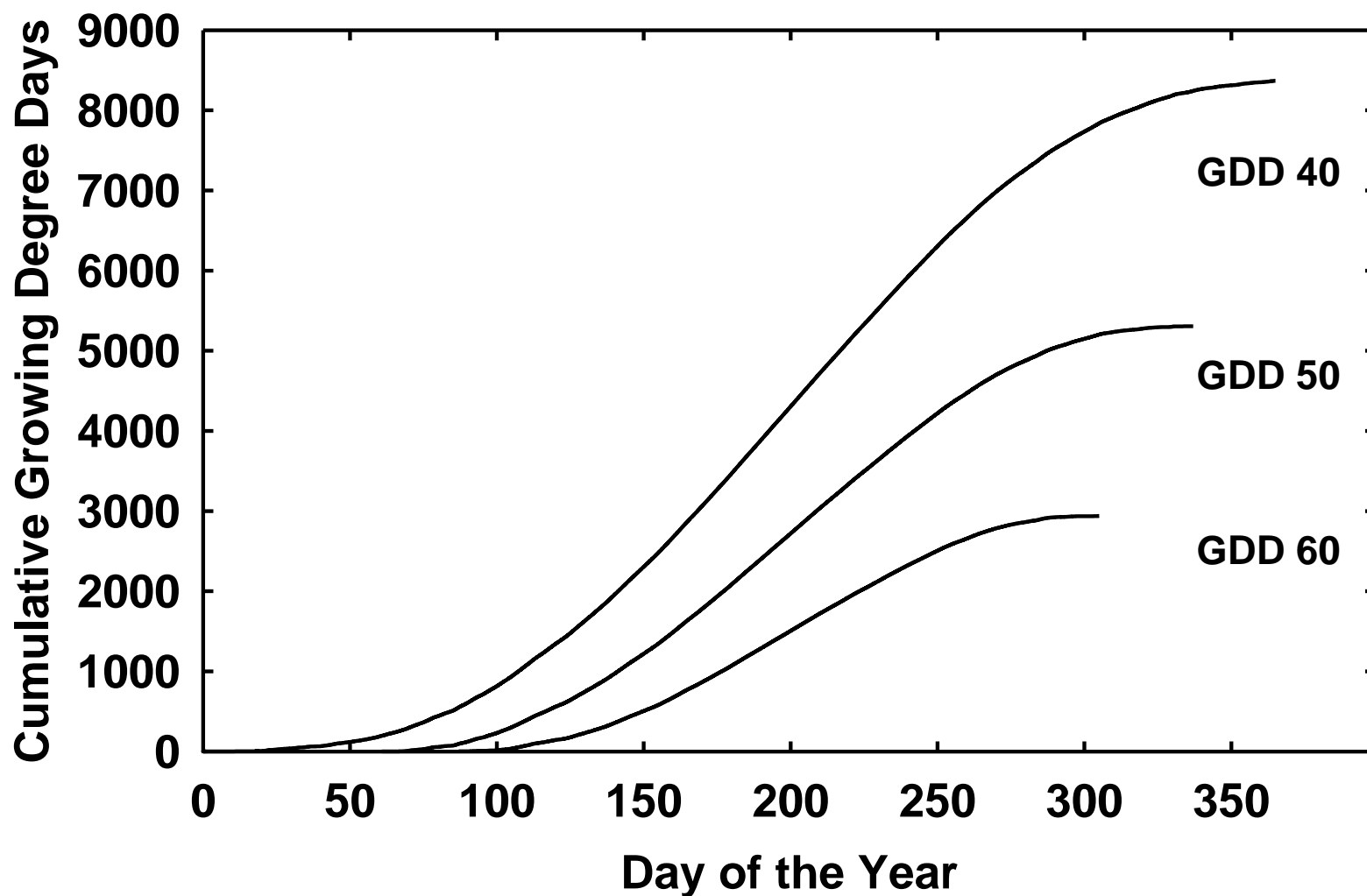
The GDD for various developmental events are as follows.

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

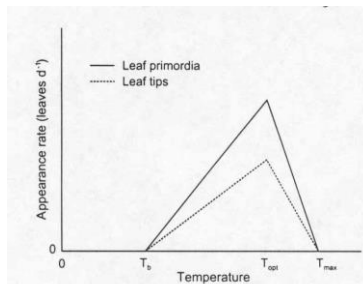


# How to use temperatures in a crop production environment?

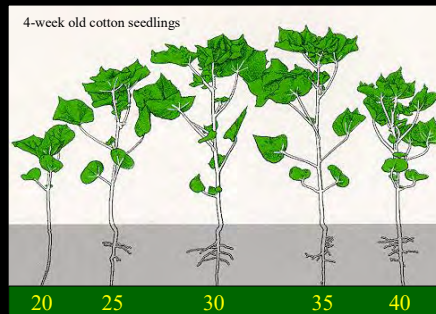
The GDD concept – Applicability or limitations:

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

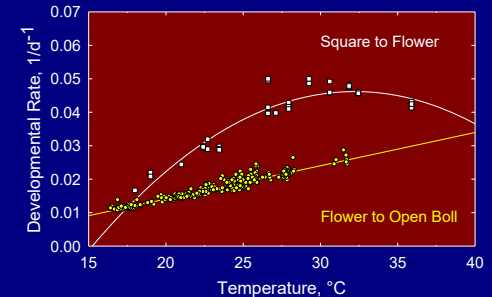
Temperature and idealized leaf developmental rates



Crop Growth and Development - Environment  
Response to Temperature



Temperature and Idealized Reproductive Rate Responses  
Square to Flower, Flower to Open Boll



- The GDD concept and it's use:

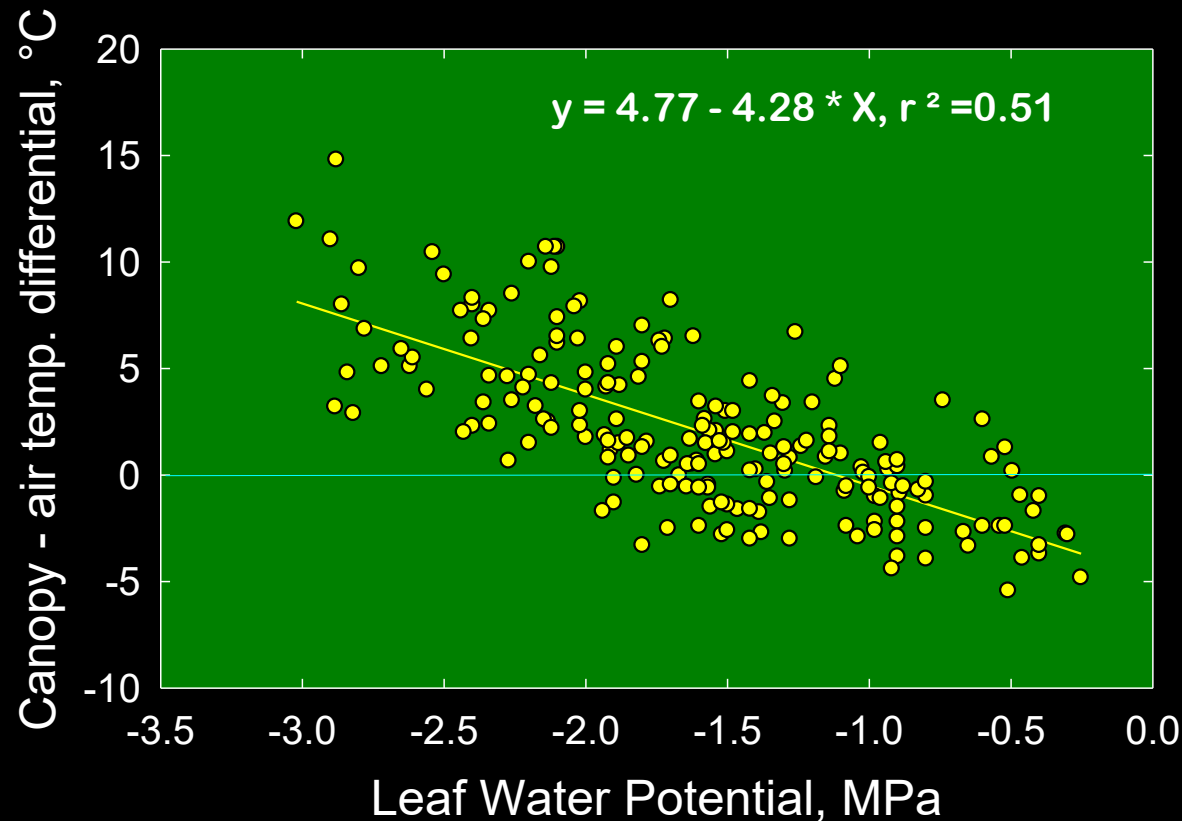
- ✓ No consideration for stresses, for example in dry or nutrient deficit environments, the rate of development will be delayed or hastened depending upon the stress condition.

# How can we use temperatures in a crop production environment?



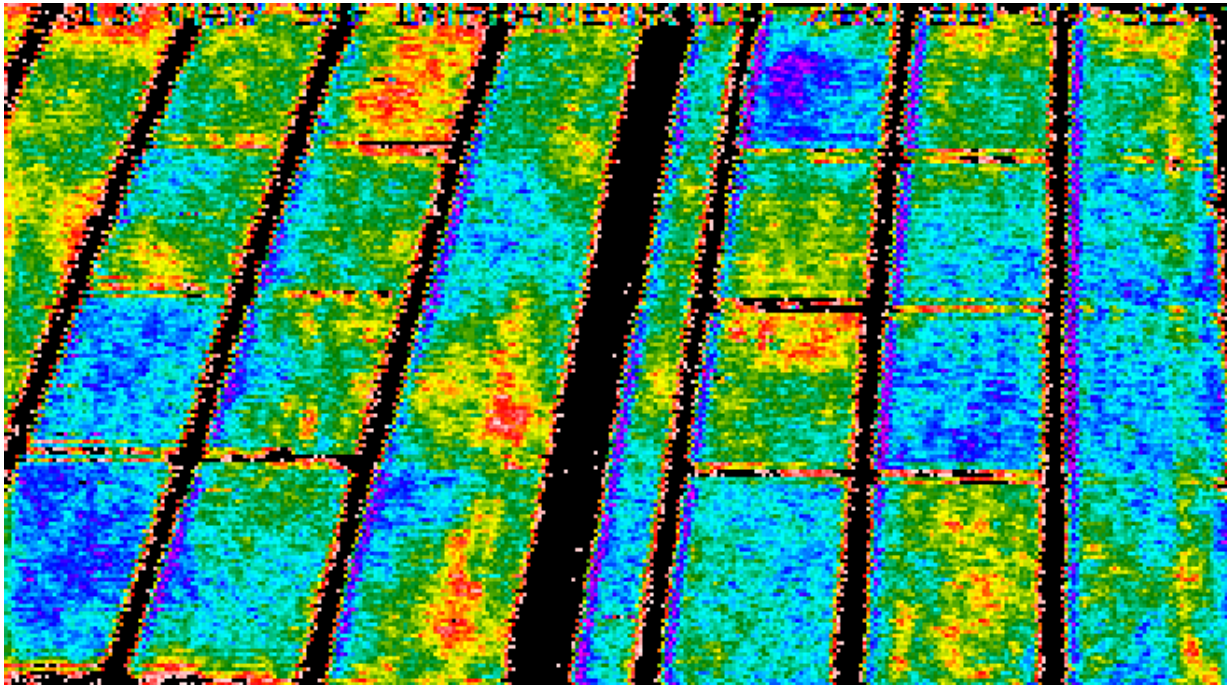
## Temperature - Plant Growth Air and Canopy Relationships

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# 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.