Environmental Plant Physiology

Photosynthesis - Aging

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Photosynthesis and Environment
Leaf and Canopy Aging

Goals and Learning Objectives:

- To understand the effects of leaf and canopy aging on photosynthesis process at leaf and canopy level.
  - Photosynthesis and leaf-level aging.
  - Photosynthesis and canopy-level aging.

Senescence, Aging and Death and Agriculture

- Senescence, aging, and death – conceived in the past as inevitable, negative processes (wear and tear phenomenon), but now considered as an internal part of differentiation and development.
- Leaf senescence is one of the most conspicuous processes that has been studied in the context of plant aging and senescence.
- The terminal phase of leaf development cannot be described simply as a collection of passive and deteriorative processes during which gradual decline in vital systems takes place.

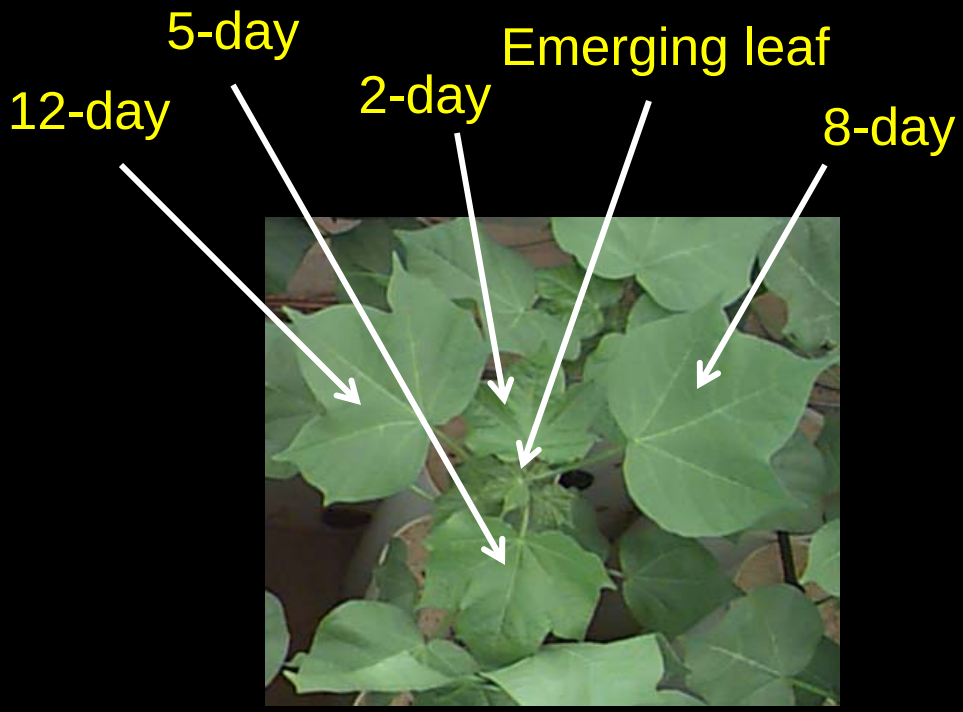
Senescence, Aging and Death and Agriculture

- Extensive physiological and biochemical studies in the last few decades on leaf senescence have suggested that it is highly regulated and active process, which is characterized by differential and sequential changes in almost every sub-cellular compartment.
- Leaf aging or senescence has implications on agriculture, affecting crop yield and the shelf life of leafy vegetables.

Photosynthesis - Aging
Leaf Level

Leaf and canopy development and aging process

Leaf



About to abscise

Canopies

Emergence

Squaring

Flowering

Mature crop

Photosynthesis - Aging
Leaf Level

Deep Inside

Unfolding leaf

Mature leaf

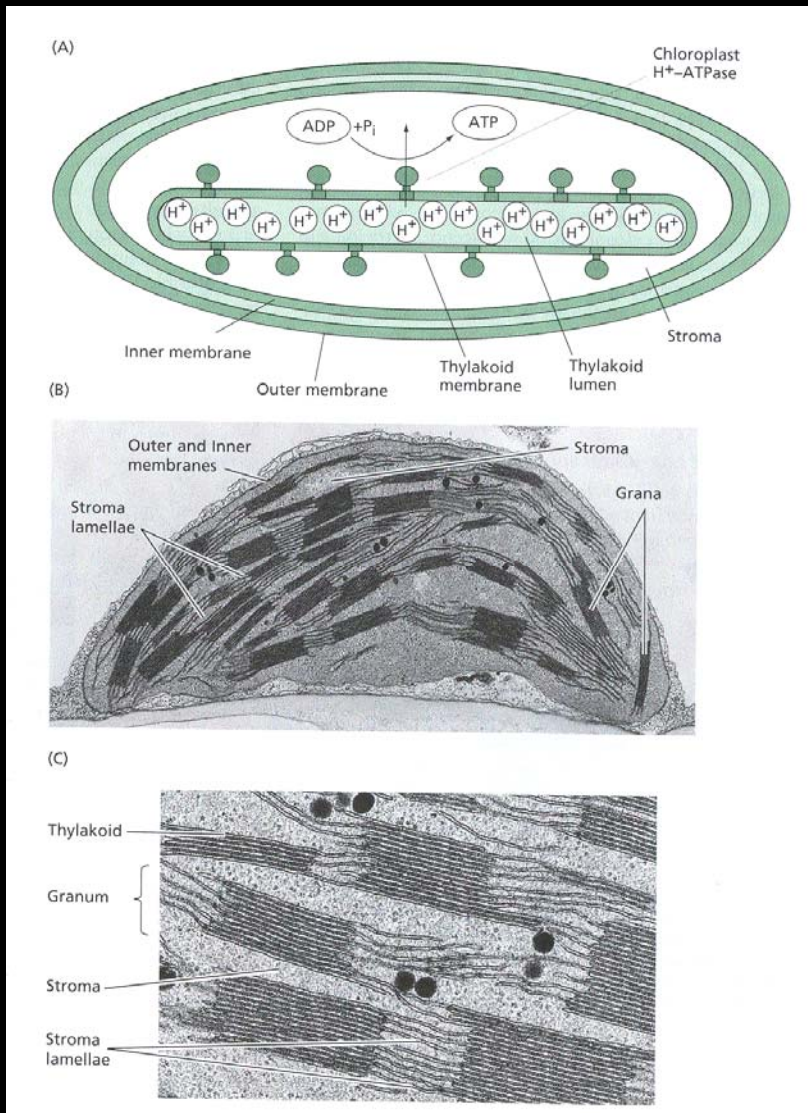
Chloroplasts with limited thylakoid development

Chloroplasts with well-developed thylakoid

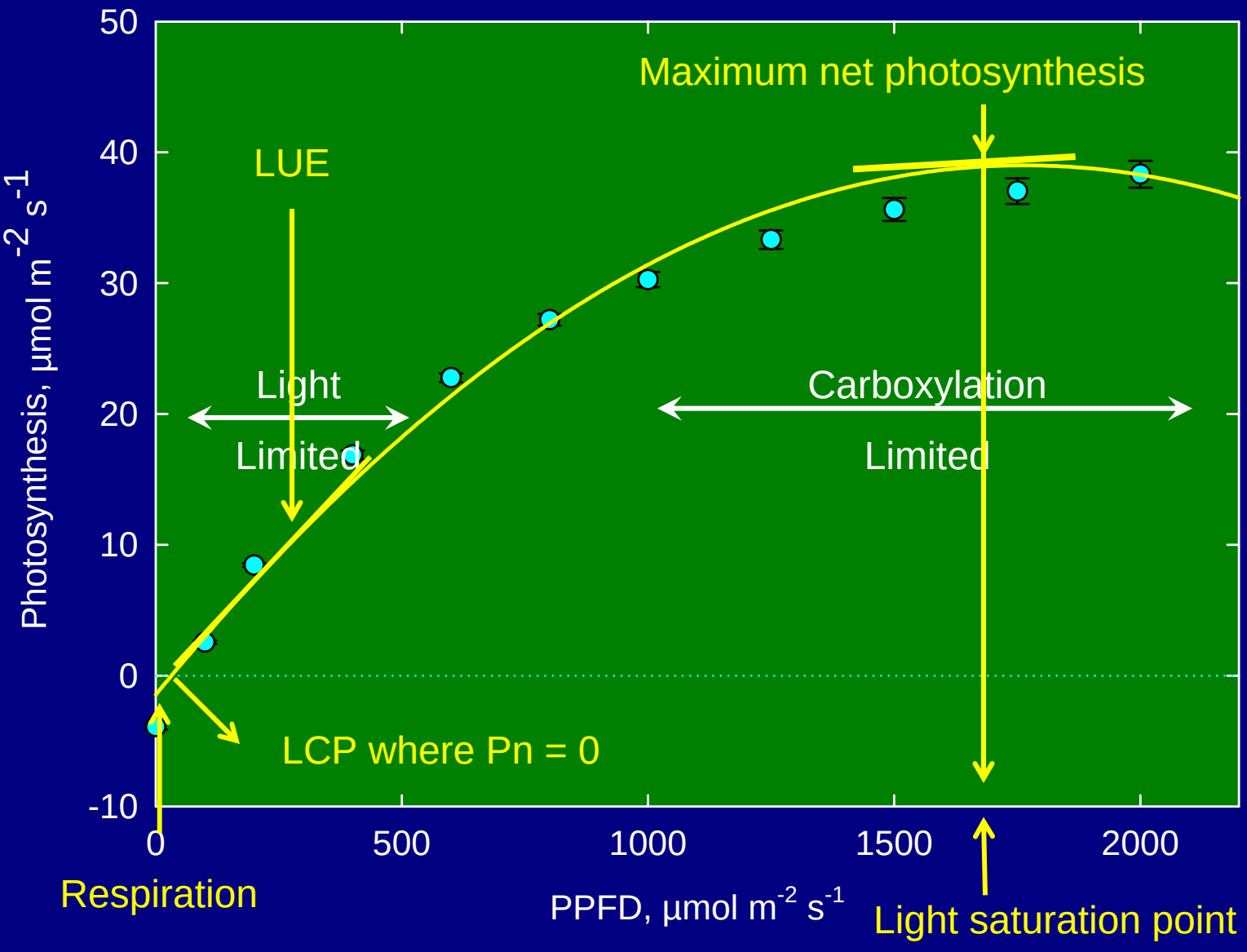
Photosynthesis - Aging
Leaf Level

Deep Inside

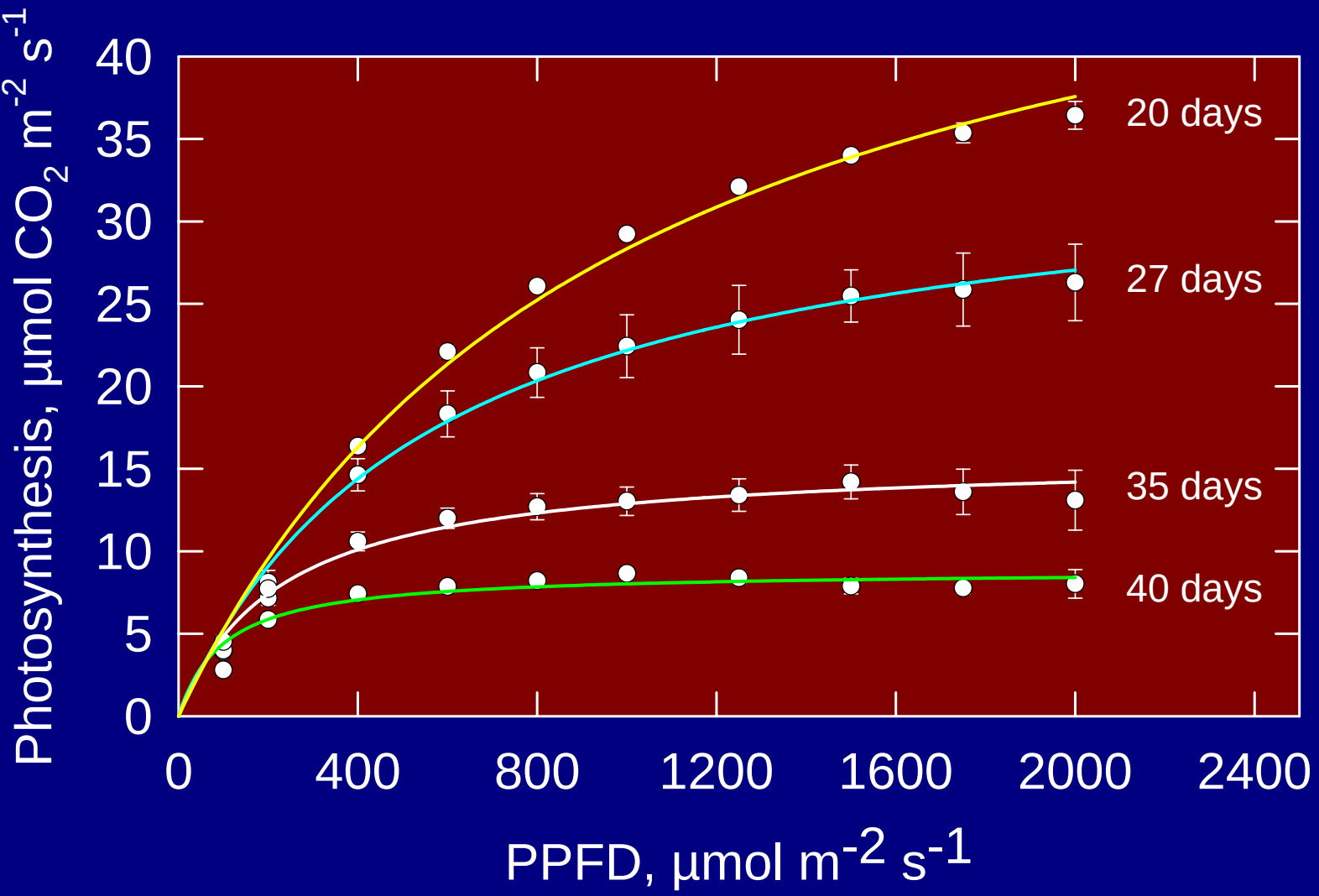
Chloroplasts contain chlorophyll and proteins, and these are the centers of photosynthesis. As leaves grow in size, these centers of photosynthesizing chloroplasts develop very well-defined thylakoids for optimum photosynthesis. Proteins and pigments that function in the photochemical events of photosynthesis are part of the thylakoid.



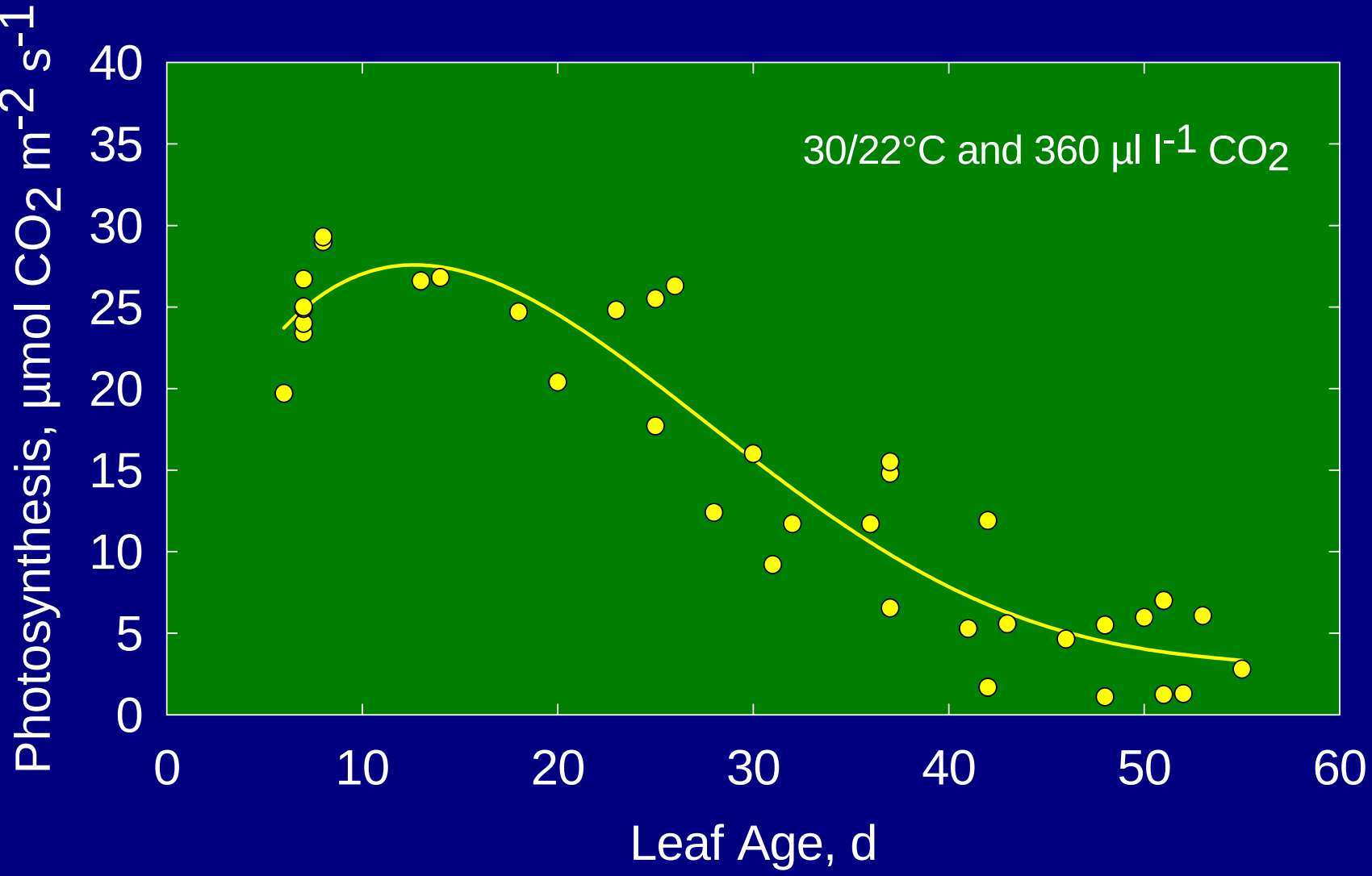
Photoynthesis and Light Response Curves



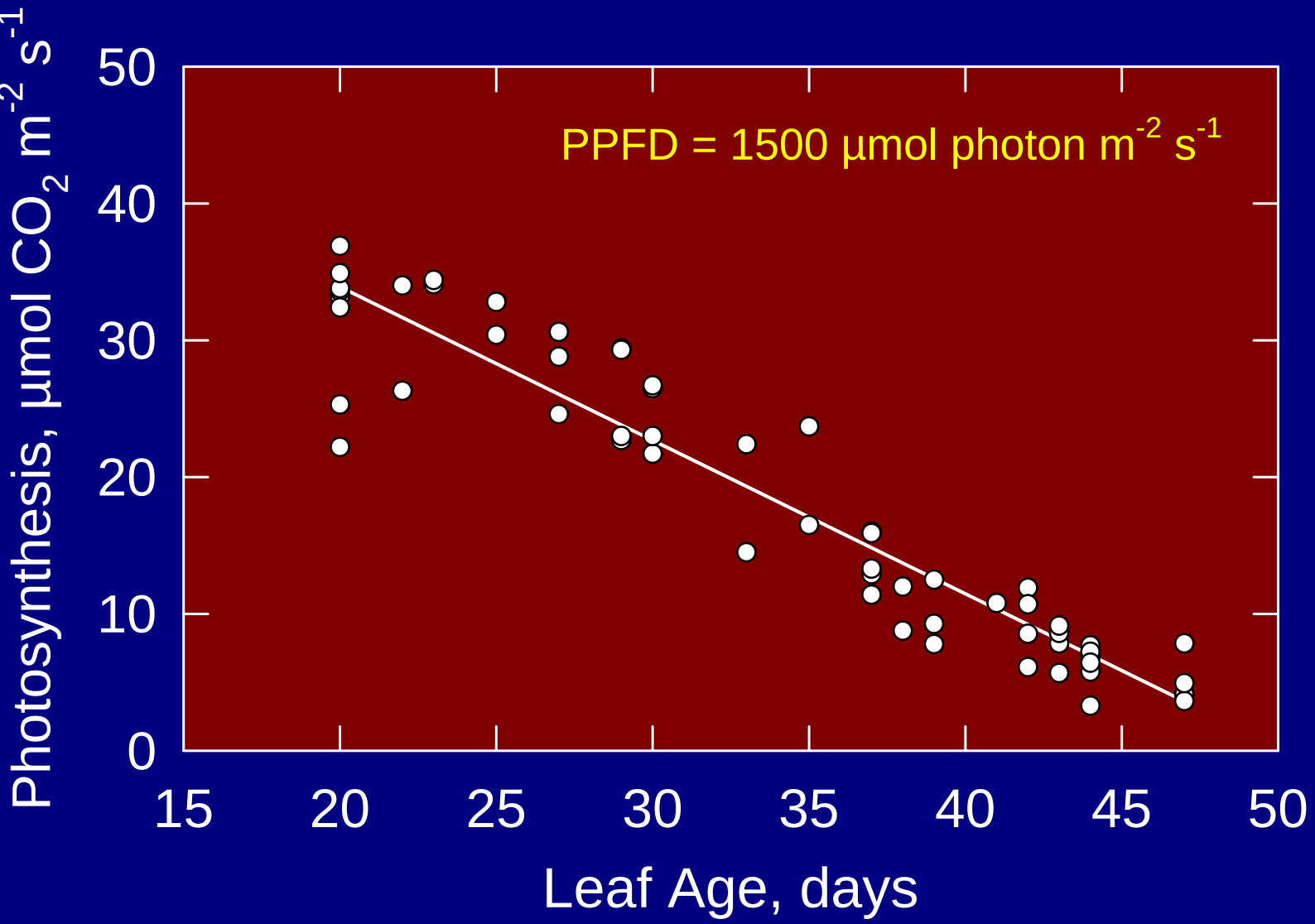
Aging - Photosynthetic Light-response Curves for Cotton Leaves



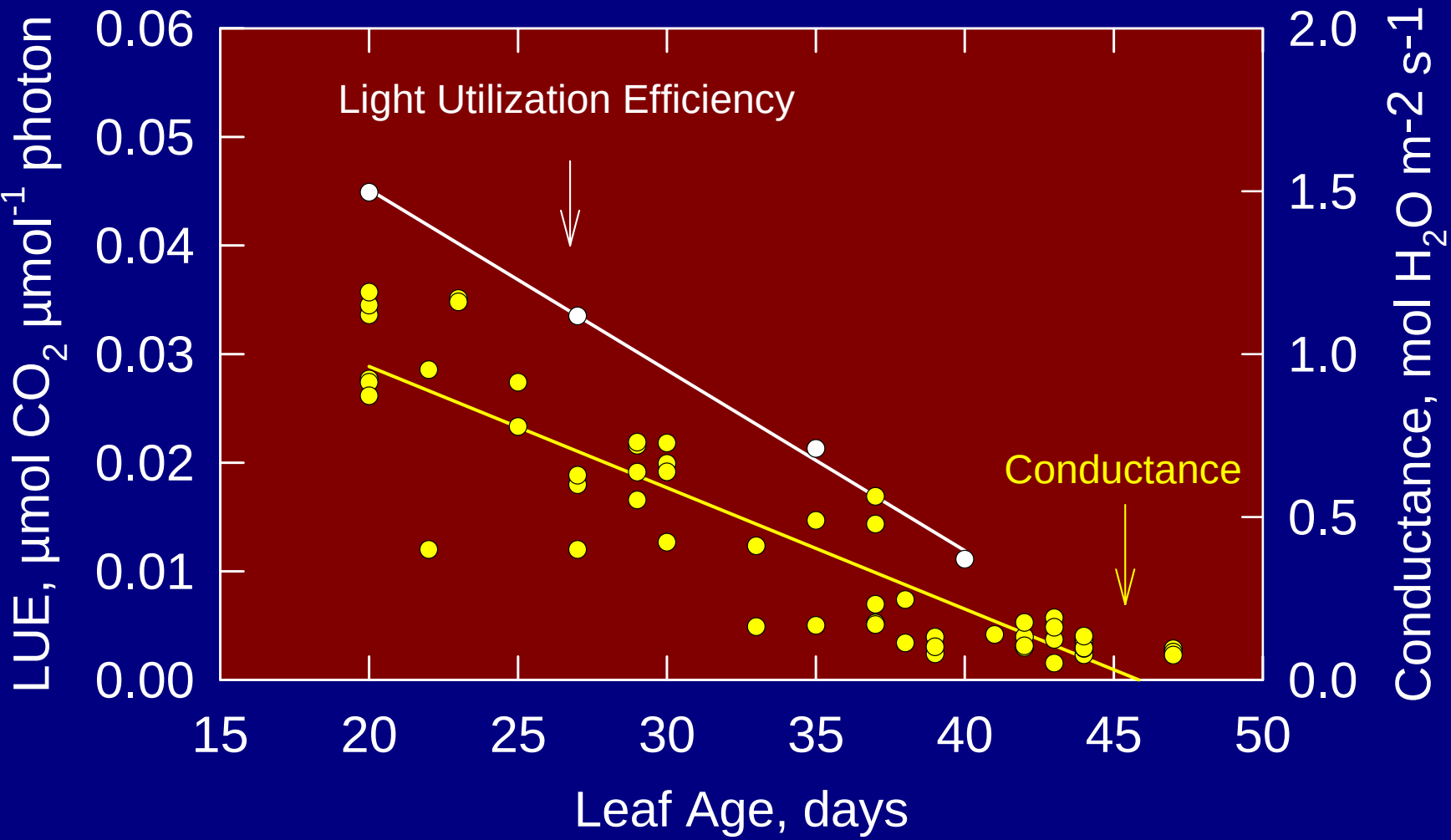
Leaf Aging and Photosynthesis



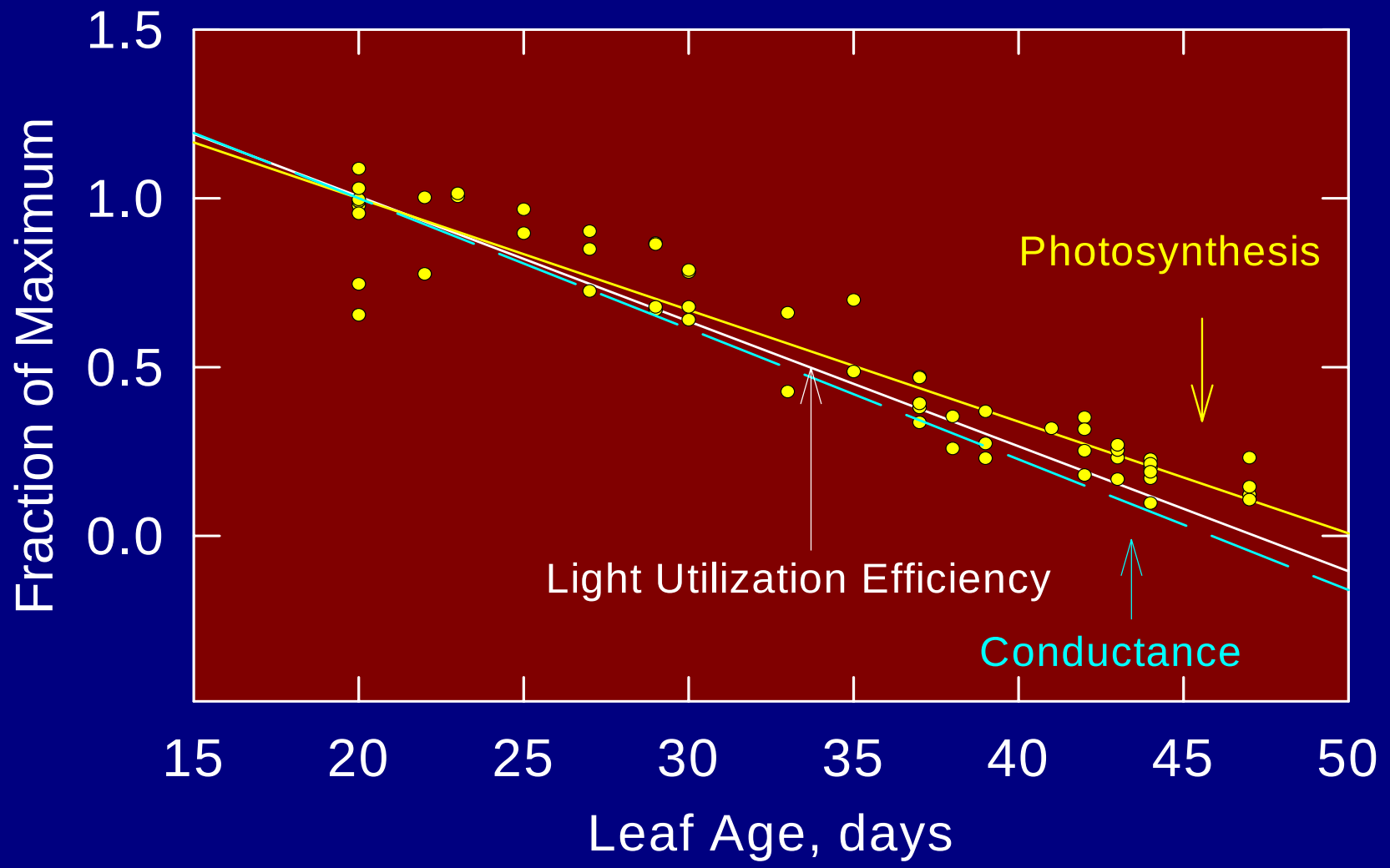
Leaf Aging and Photosynthesis



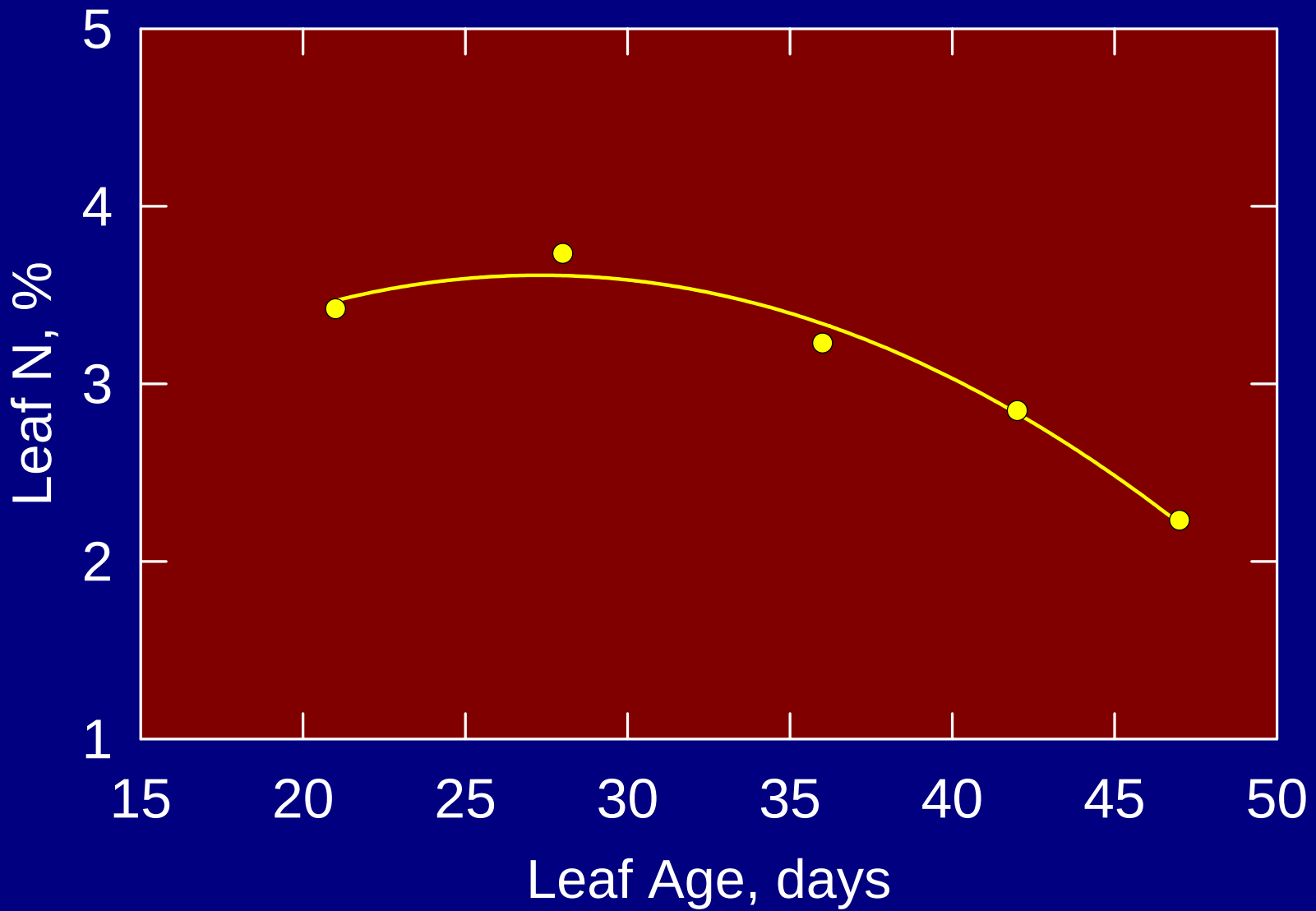
Leaf Aging and Light Utilization Efficiency and Conductance



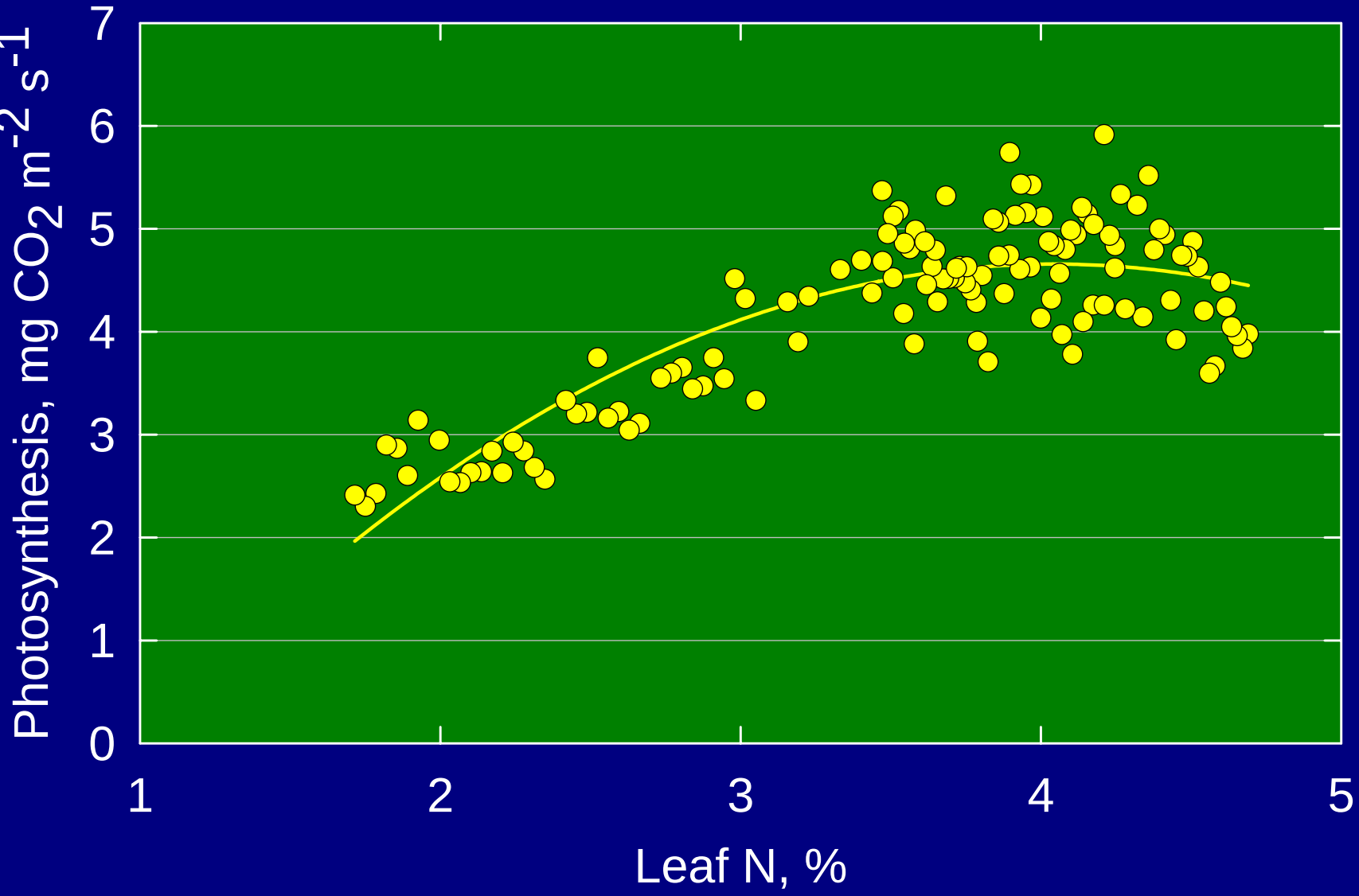
Leaf Aging - Photosynthestic Parameters Expressed as Fraction of Maximum (= 20 d)



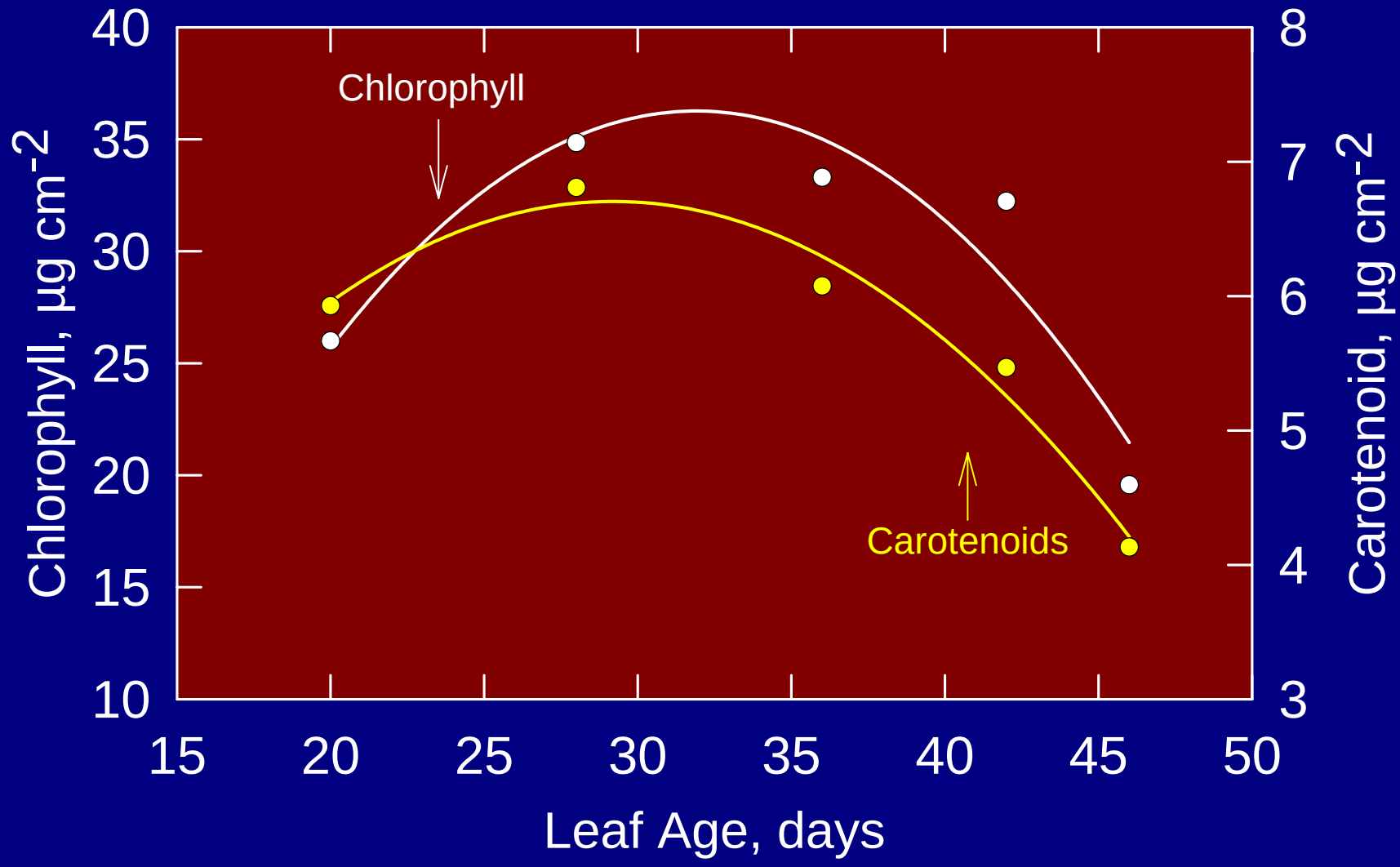
Leaf Aging and Leaf Nitrogen

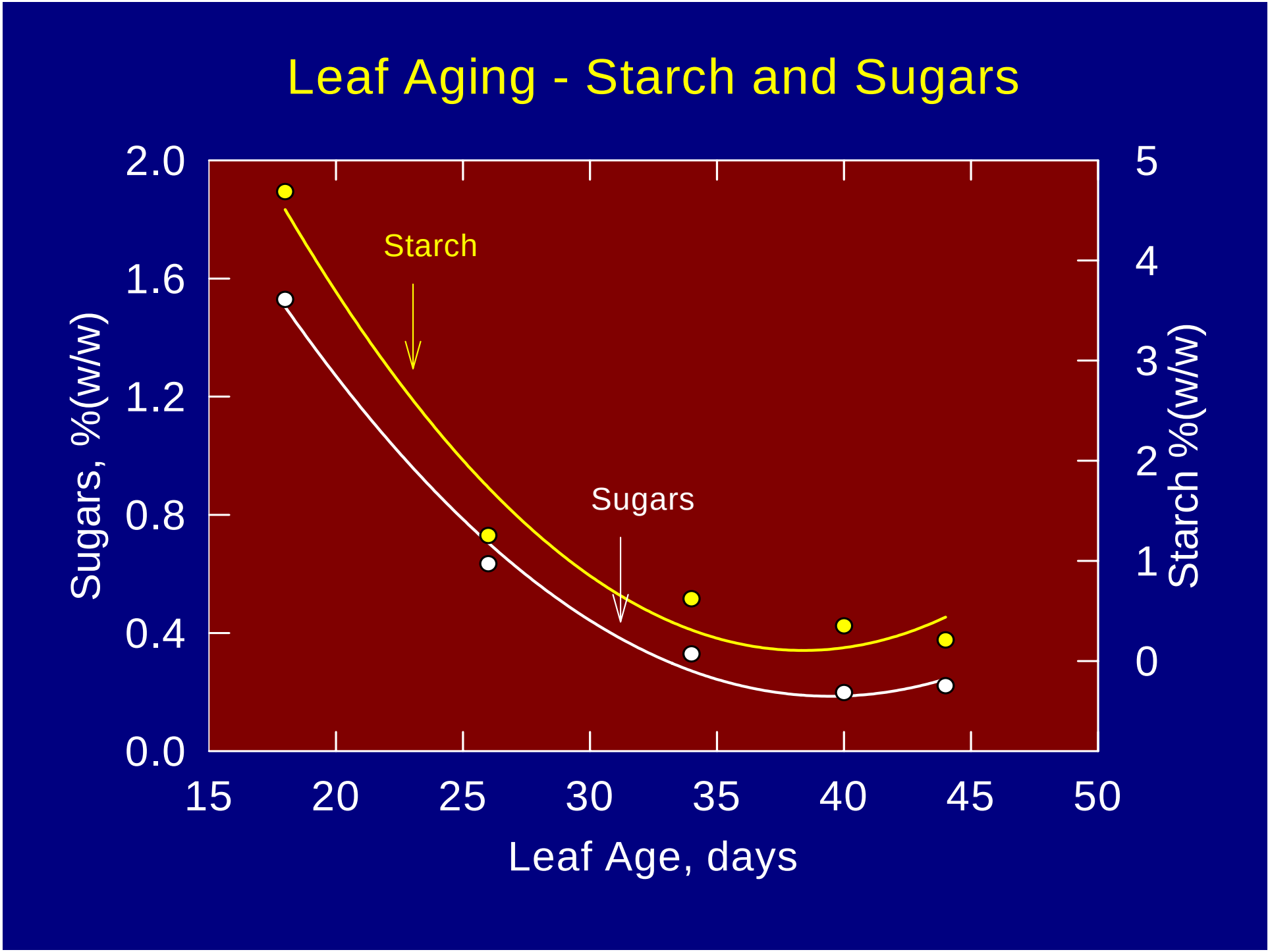


Photosynthesis - Leaf Nitrogen



Leaf Aging - Leaf Pigments
Chlorophyll and Carotenoids




Leaf Aging - Starch and Sugars
Starch
Sugars
Sugars, %(w/w)
Starch %(w/w)
Leaf Age, days
2.0
1.6
1.2
0.8
0.4
0.0
5
4
3
2
1
0
15
20
25
30
35
40
45
50

Leaf Aging and Photosynthesis

- As leaves grow in size, leaf net photosynthesis increases rapidly from leaf unfolding (about zero at leaf unfolding) until the leaf reaches its potential maximum size. Soon thereafter (from about 20 days from unfolding), leaf net photosynthesis declines linearly. Light saturation occurs at lower light levels as leaves age.
- The onset (from about 20 days) and magnitude (rates) of declines in leaf conductance and light utilization efficiencies are closely coupled with leaf maximum photosynthesis rates.
- Leaf transpiration rates closely followed photosynthetic rates throughout the leaf development.
- Leaf pigments (chlorophylls and carotenoids) decline from about 35 days from leaf unfolding, at least in cotton.

Leaf Aging and Photosynthesis

- The concentration of CO_2 inside the leaf (C_i), and the number of chloroplasts in the mesophyll remain nearly constant during the aging process, except in the oldest leaves that are about to abscise.
- Total leaf protein content, RuBP carboxylase and electron transport activity decline parallel to photosynthesis during the aging process.
- Leaf N also declines from about 20 days, but the decline was not as dramatic as the photosynthetic parameters.
- The levels of starch and sugars also decrease during the aging process suggesting the loss of photosynthetic activity.
- Therefore, the physiological deterioration of leaf photosynthetic activity during the aging process may be more related to declining Rubisco protein (photosynthetic capacity) and photosynthetic efficiency (LUE) than to leaf N, leaf pigments and number of chloroplasts. The leaf N and pigments also play a role at a latter stage.

Leaf Aging and Photosynthesis

Varying light levels during aging by partial shading the leaf did not change leaf photosynthetic characteristics (LUE and Pmax.).

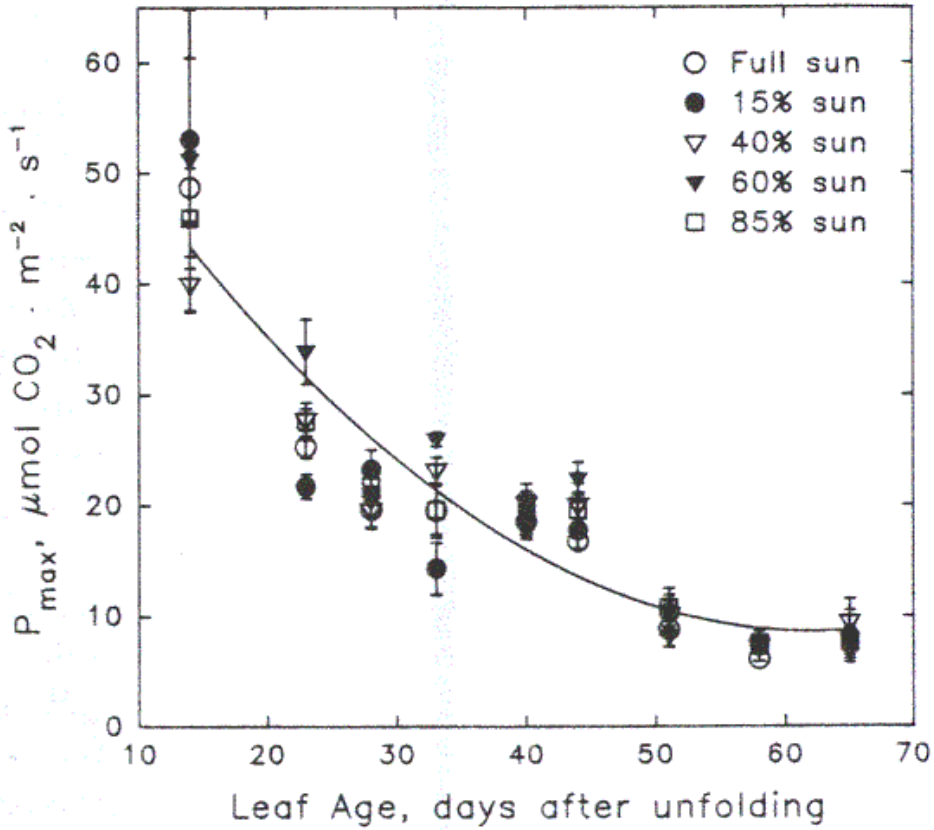
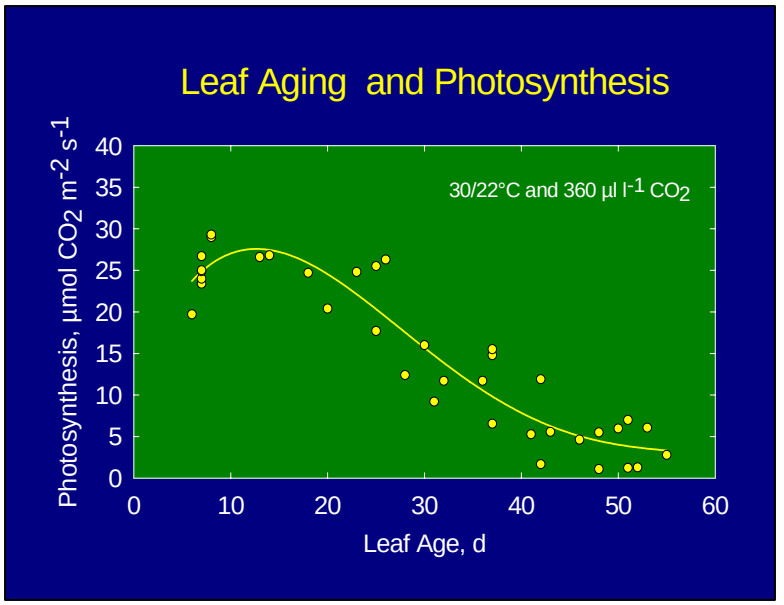


Fig. 2. Maximum photosynthetic rate (P_{max}) at saturated light, determined from the measured light–response curve using Eq. 1. P_{max} is a measure of the maximum capacity of the photosynthetic machinery under saturating light conditions. Results are means (±SE) of five leaves at each light level (15, 40, 60, 85, and 100% full sun).

Leaf Aging and Photosynthesis

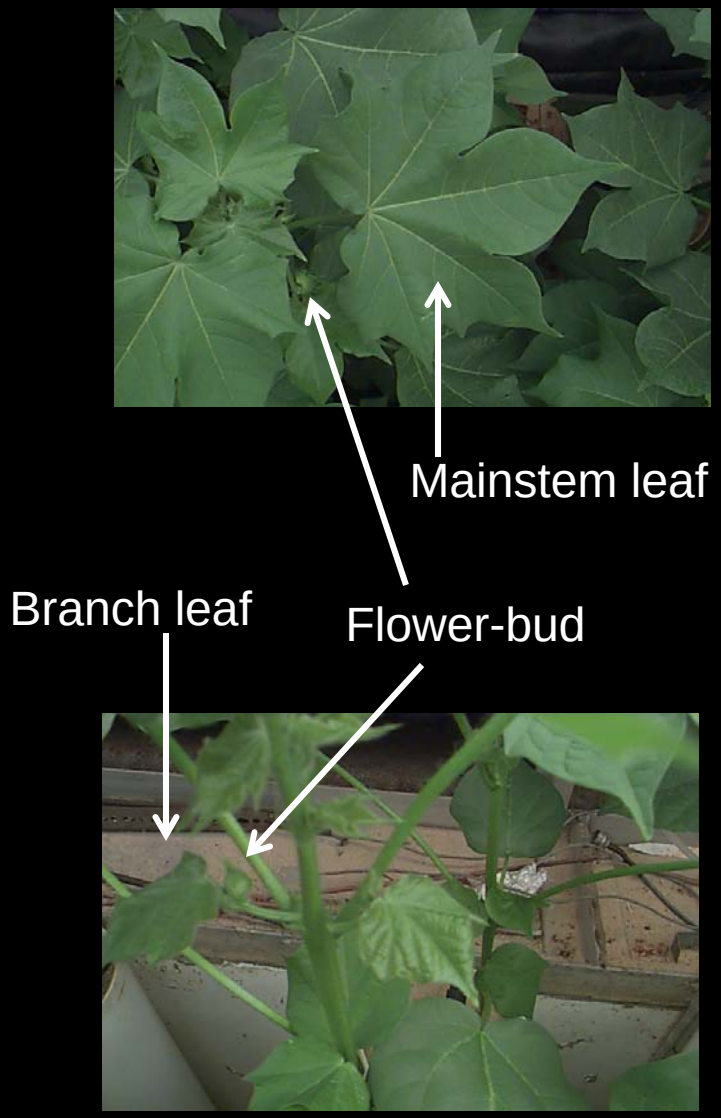
The shape and magnitude of photosynthetic capacity and efficiency did not change due to leaf location or position when measured at the same age, at least in cotton.



Leaf Aging and Photosynthesis

- In cotton, Pmax is out of sequence with carbon requirements of bolls:

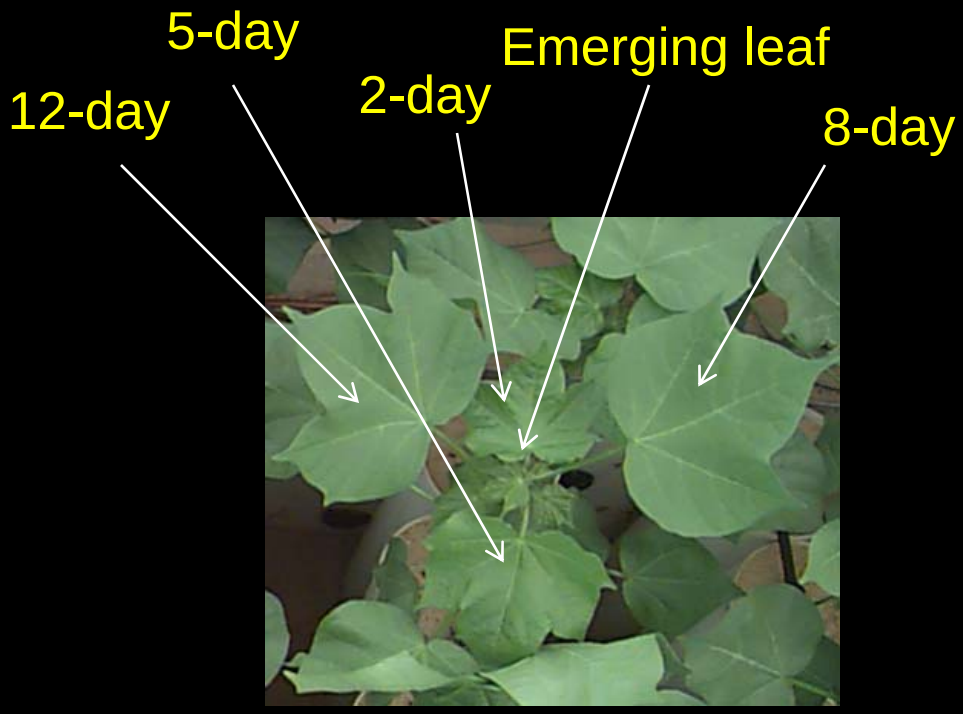
1. Mainstem leaves reach peak rates several days before flowering on the branch and rates are substantially reduced during boll-filling.
2. The branch leaves subtending flower/boll reach maximum photosynthesis (Pmax) about the time of anthesis.
3. Carbon appears to be translocated from remote sites to the developing bolls.



Photosynthesis - Aging
Canopy Level

Leaf and canopy development and aging process

Leaf



About to abscise

Canopies

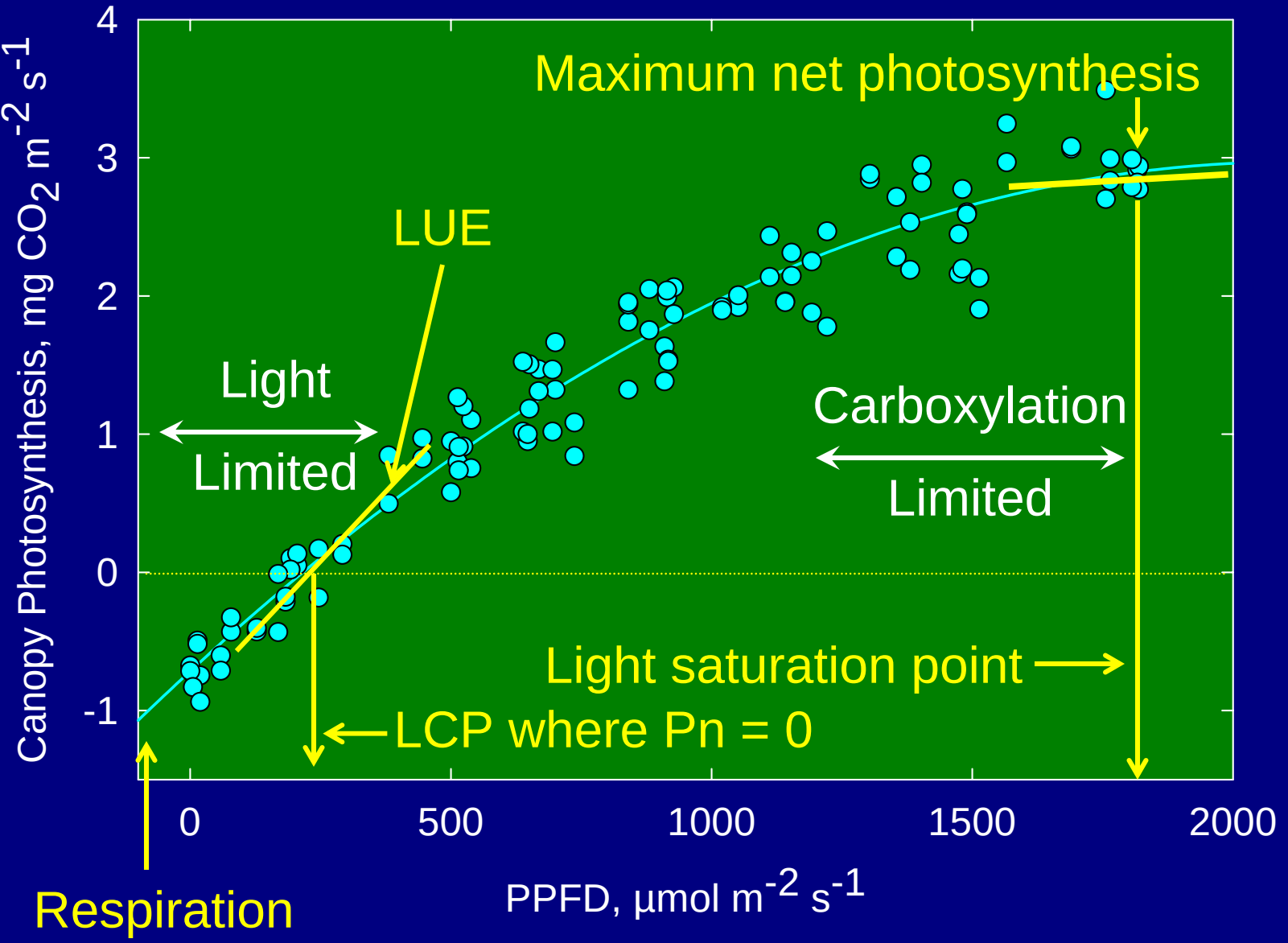
Emergence

Squaring

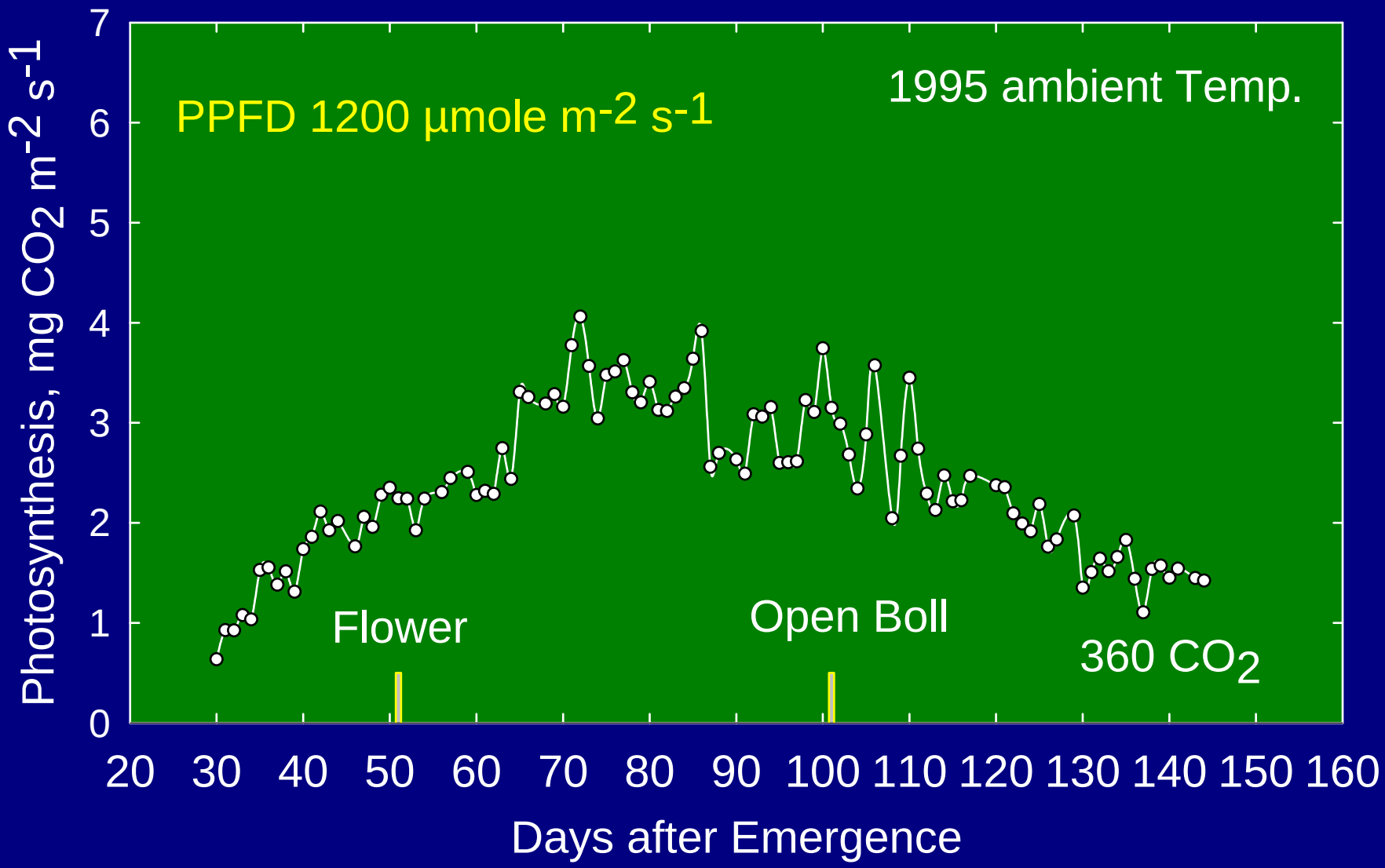
Flowering

Mature crop

Photosynthesis and Light Response Curves

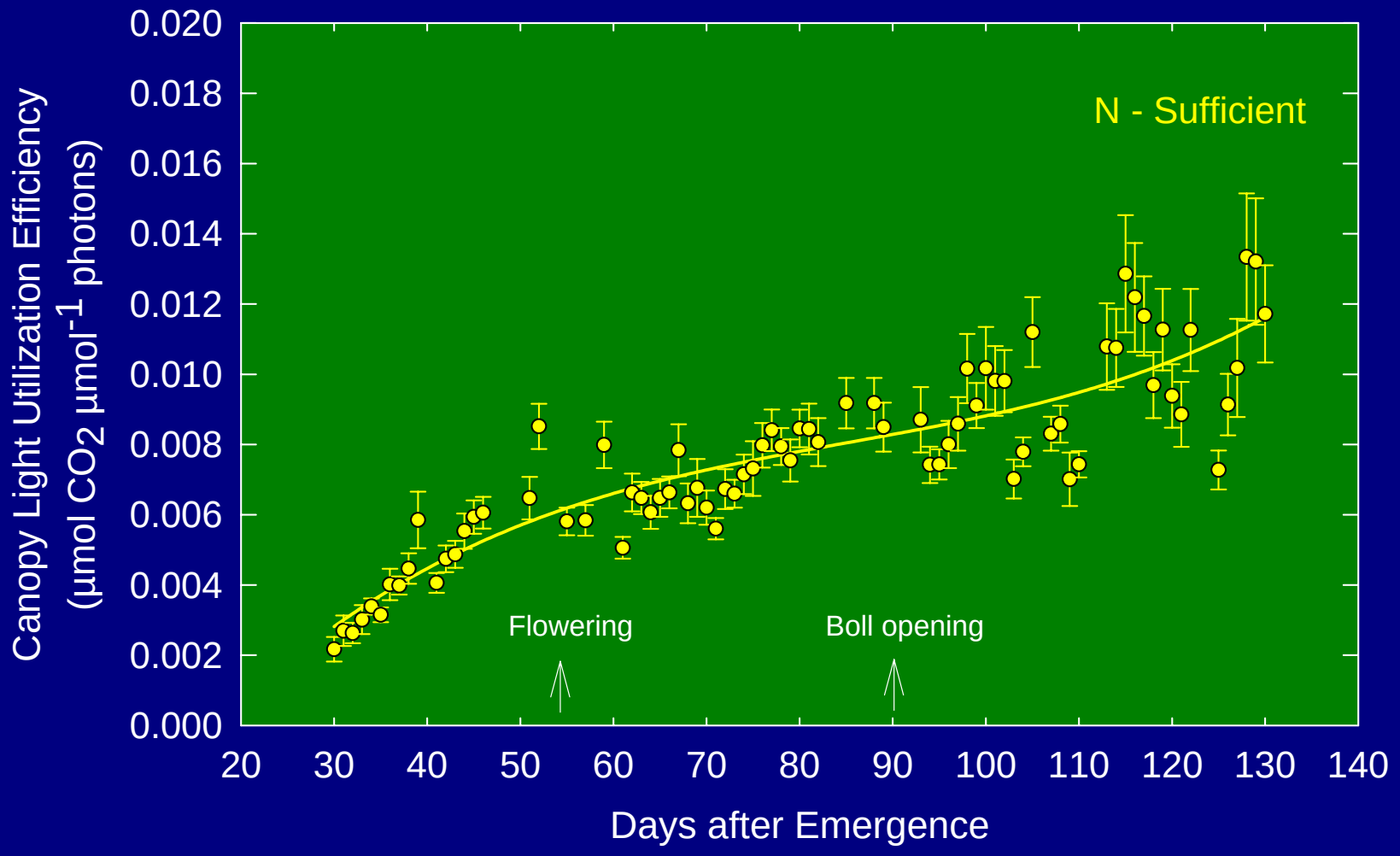


Canopy Aging - Photosynthesis



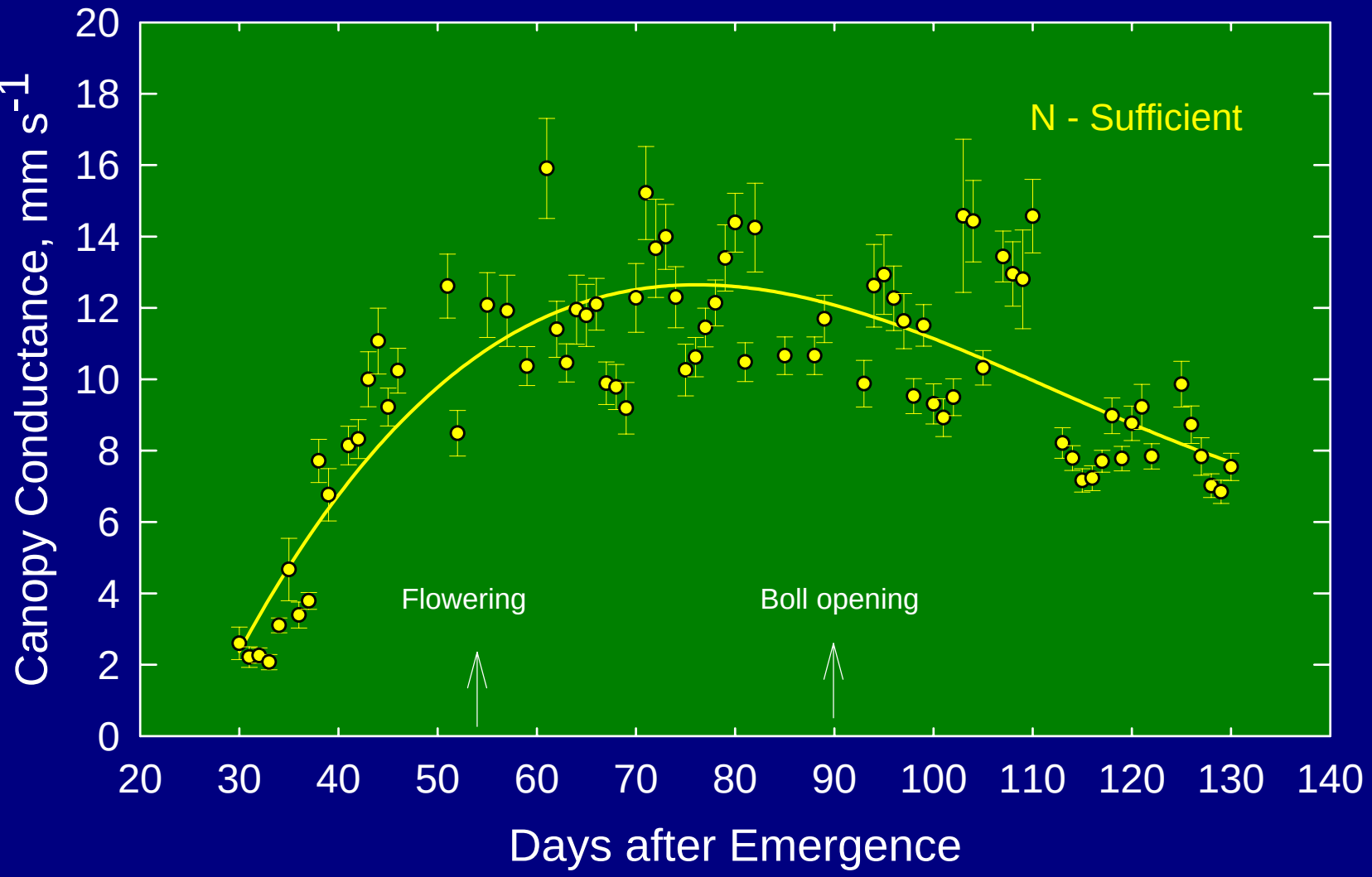
Photosynthesis - Canopy Growth and Aging

Canopy Light Utilization Efficiency



Ptotosynthesis - Canopy Growth and Aging

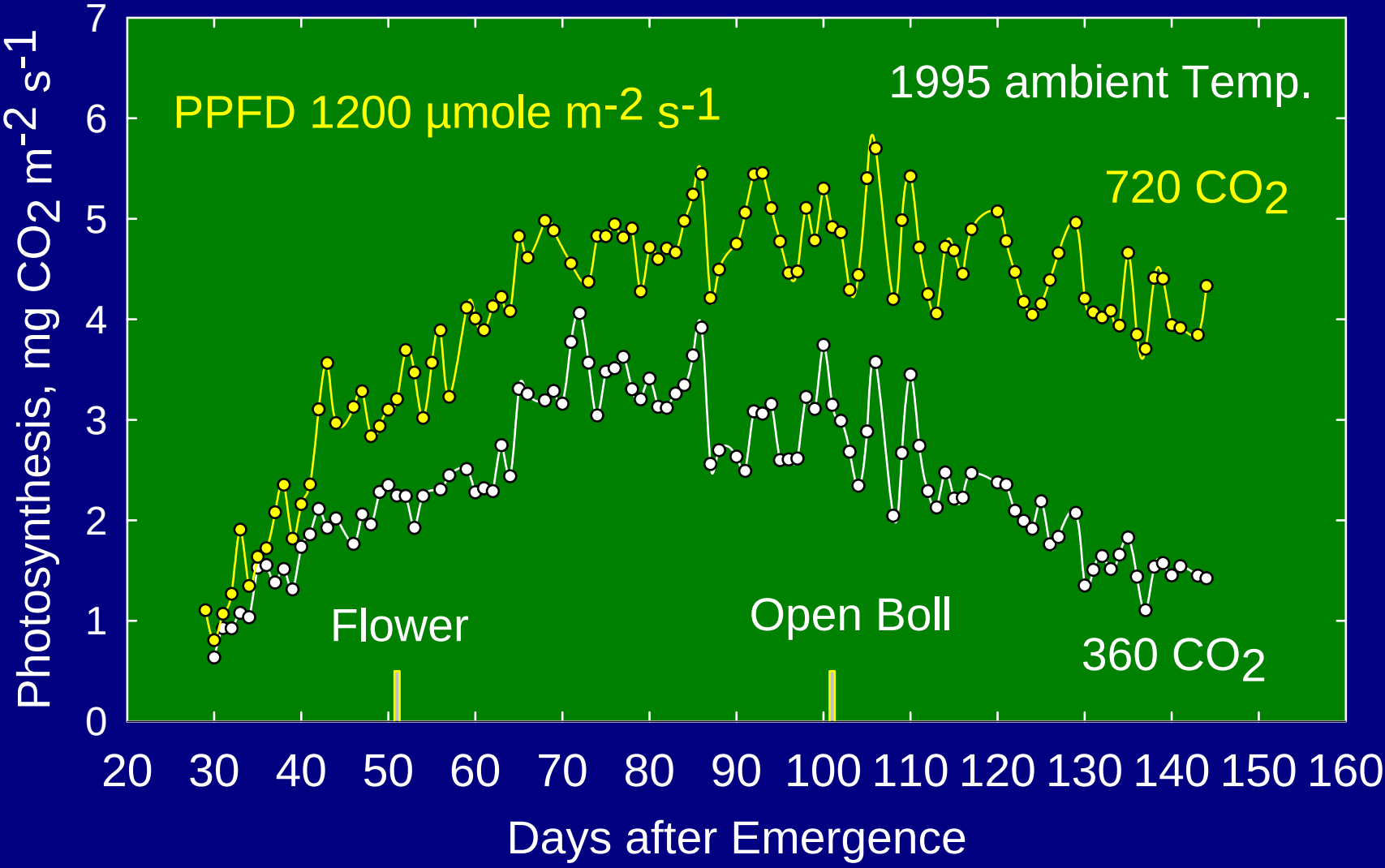
Canopy Conductance



Photosynthesis - Aging

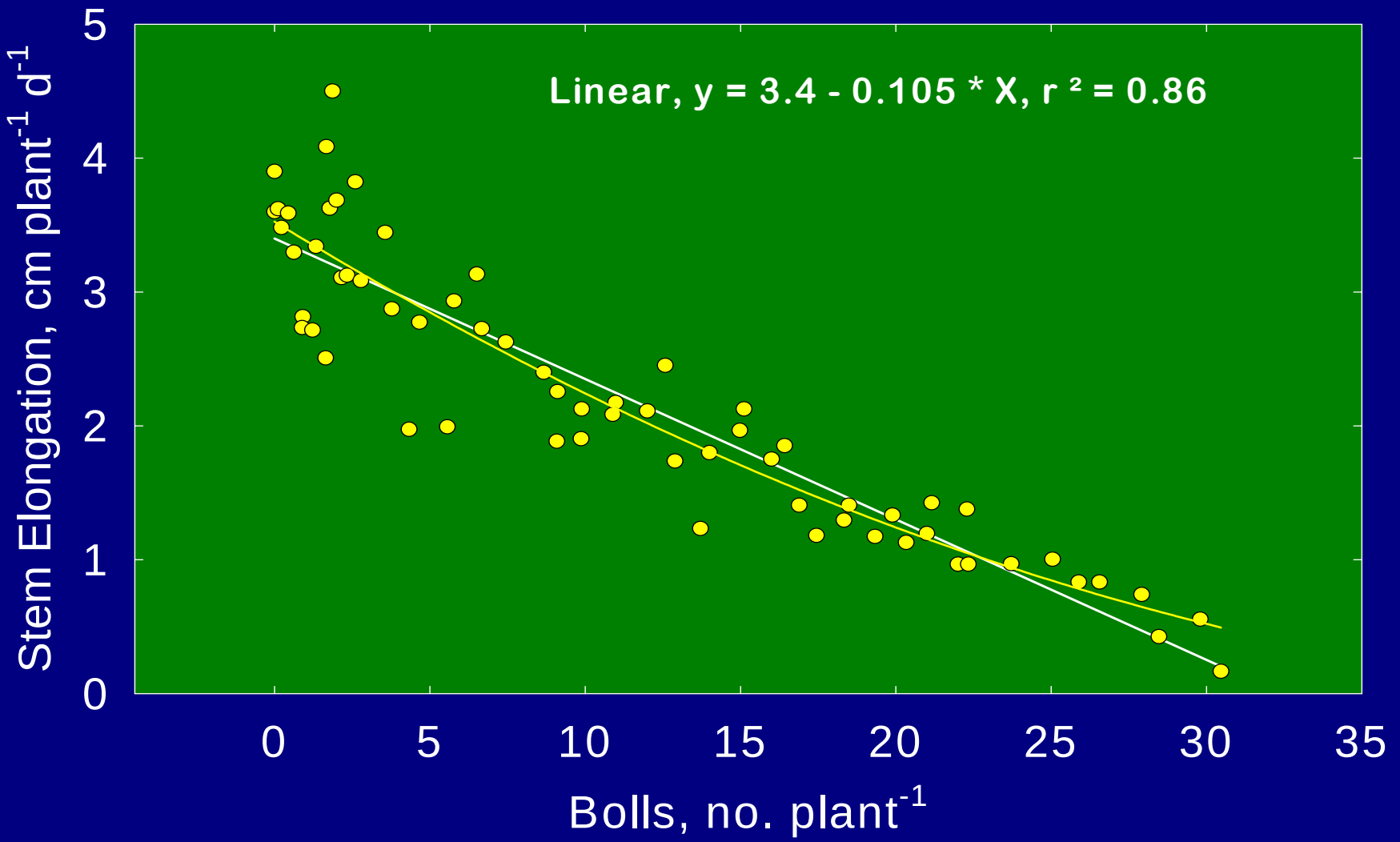
Factors controlling aging and photosynthetic process

Canopy Aging - Photosynthesis
Response to Carbon Dioxide



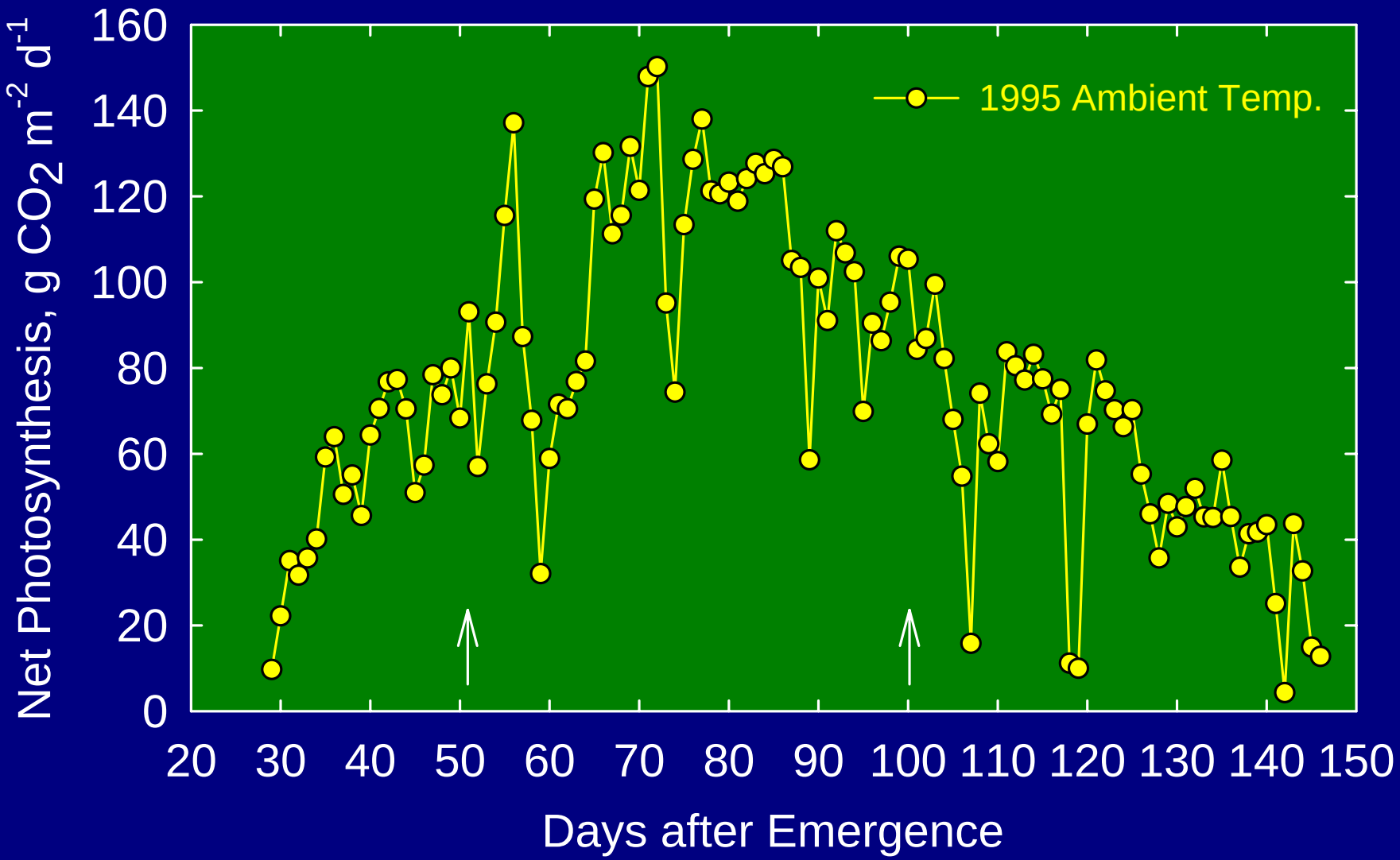
Boll-load and Vegetative Growth

Stem Elongation vs Boll Numbers



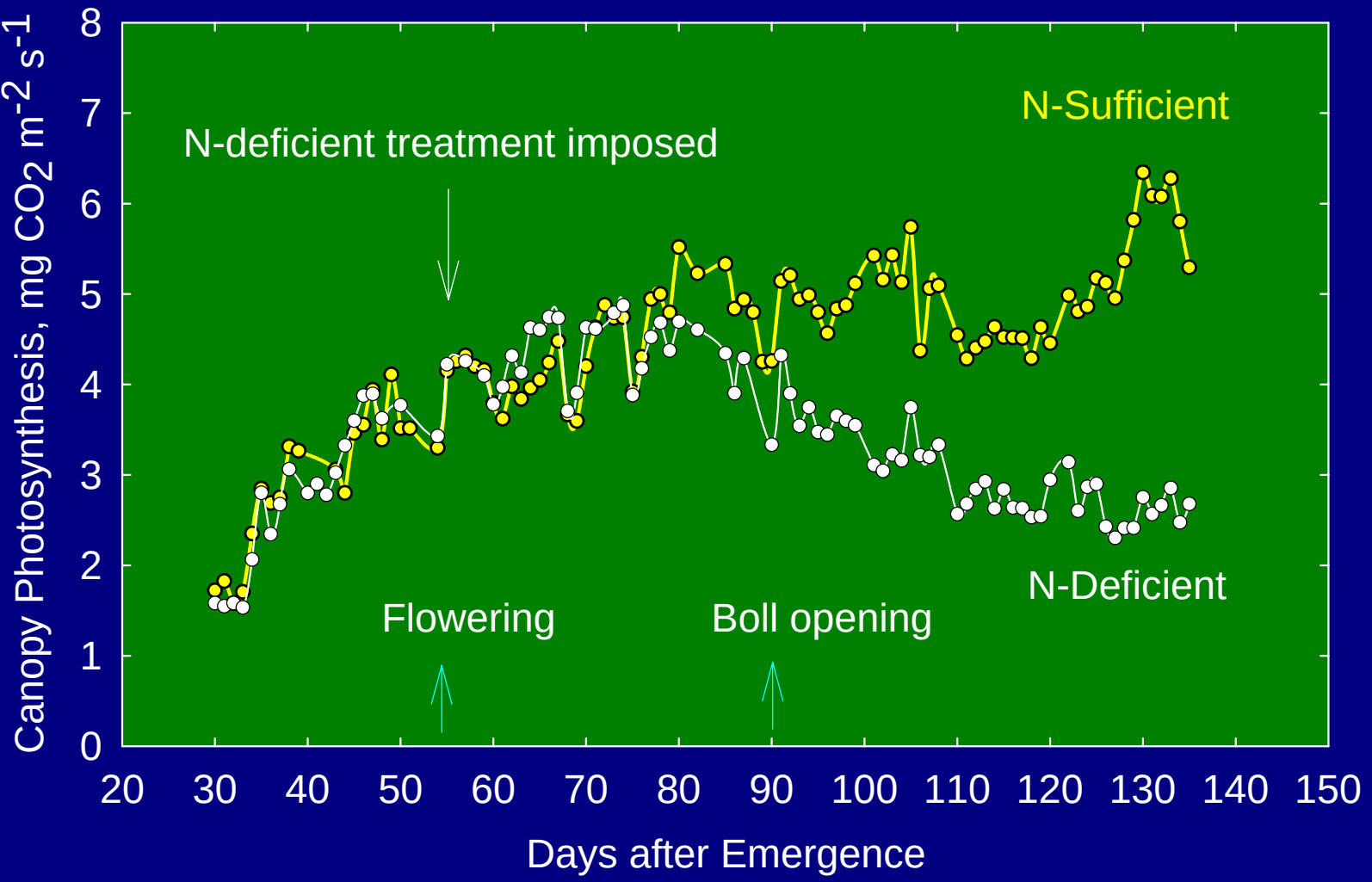
Canapy Growth - Aging - Daily Net Photosynthesis

Seasonal Trends1995

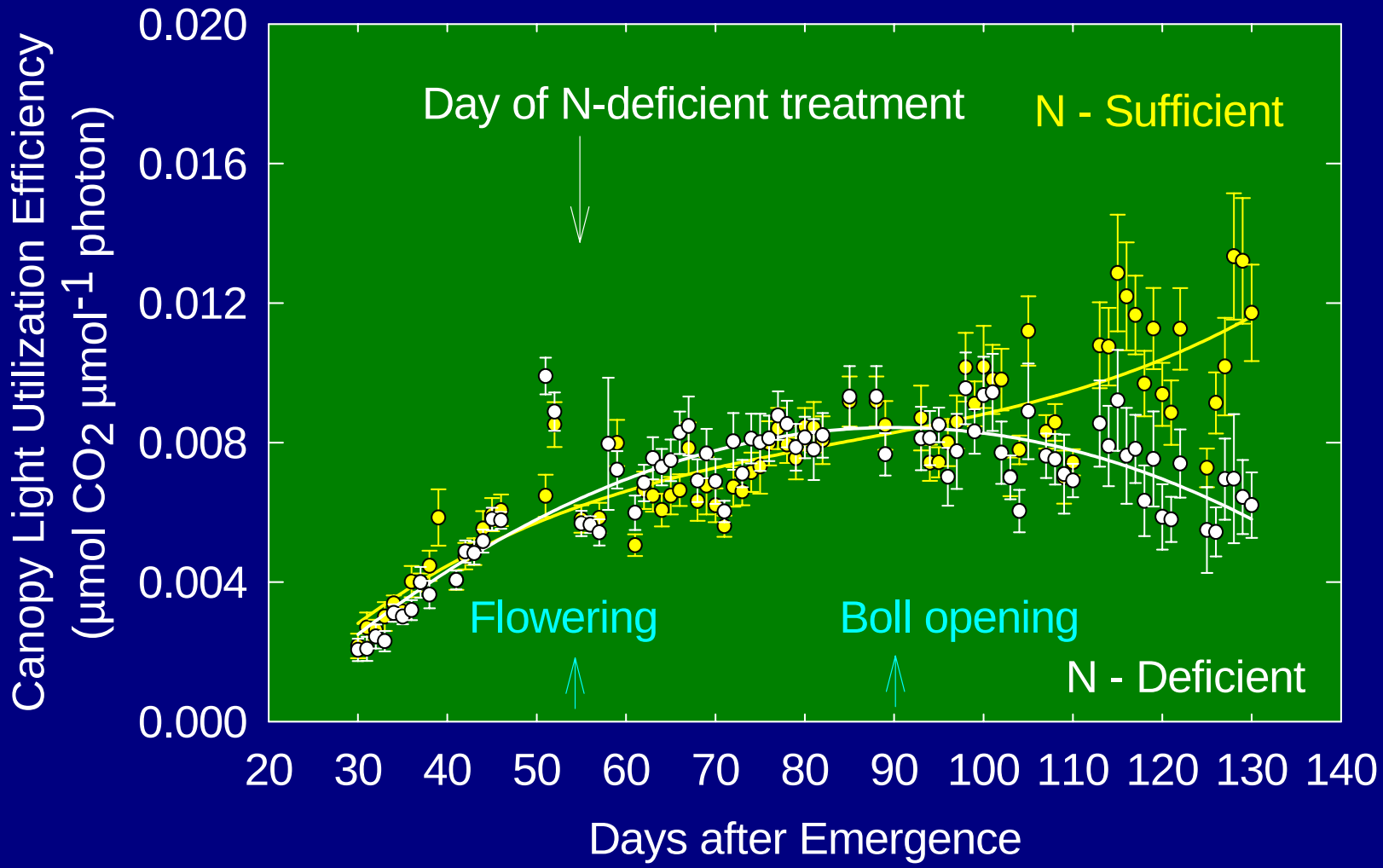


Canopy Growth - Aging - Seasonal Trends

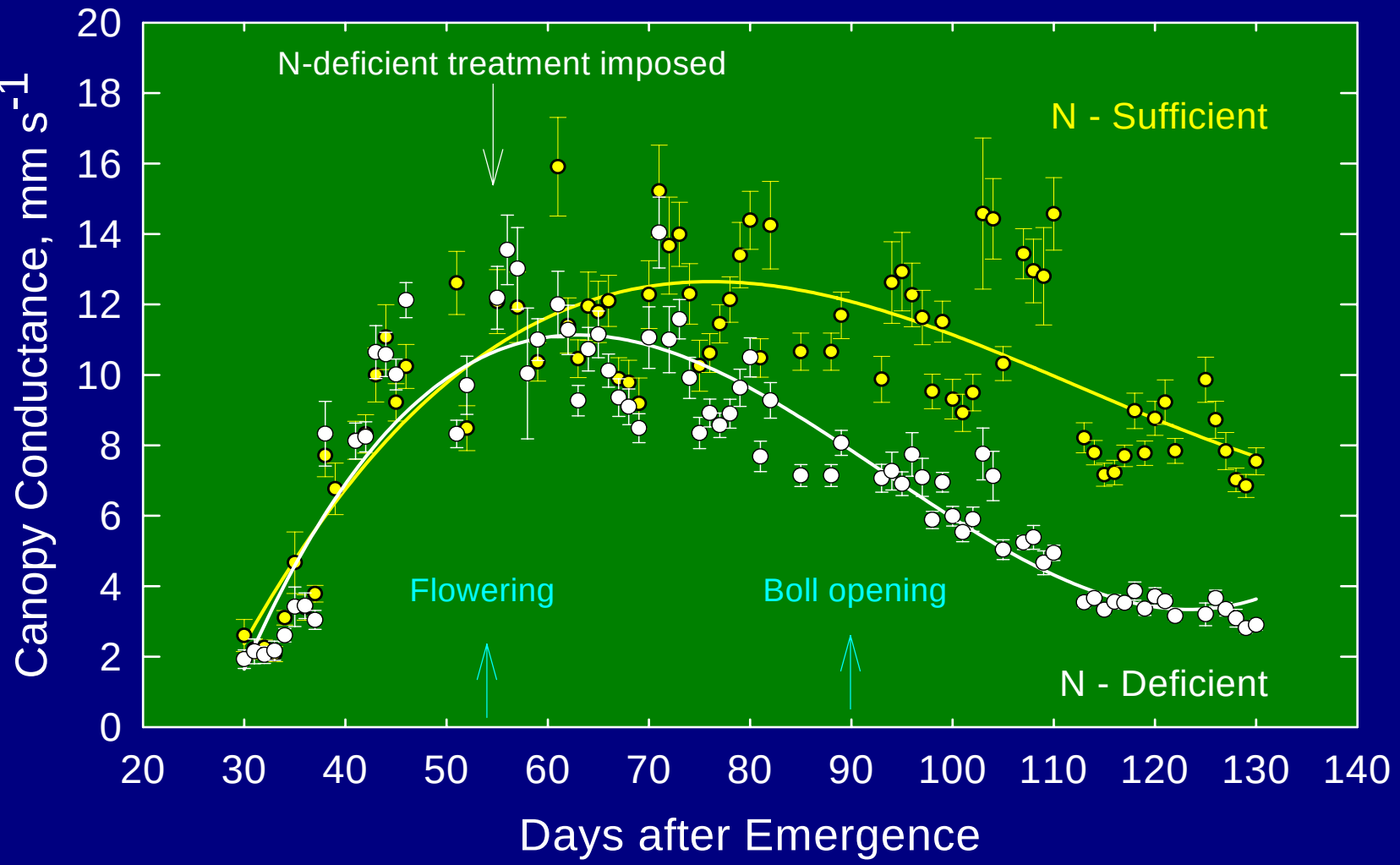
Response to Nitrogen Nutrition



Canopy Aging and Photosynthesis
Canopy Light Utilization Efficiency

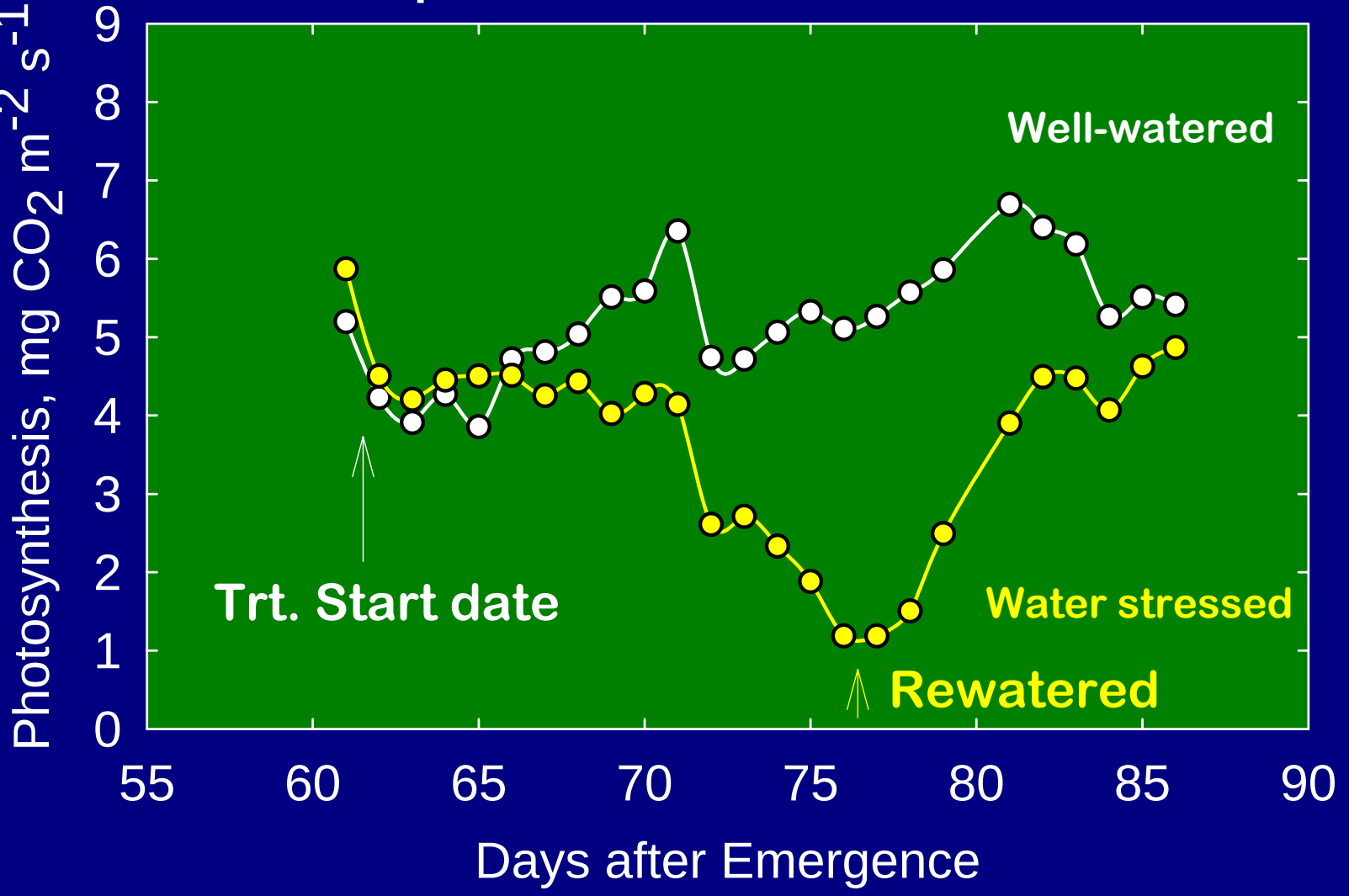


Canopy Aging and Canopy Conductance Response to Nitrogen Nutrition



Photosynthesis - Growth - Aging

Response to Water Deficits

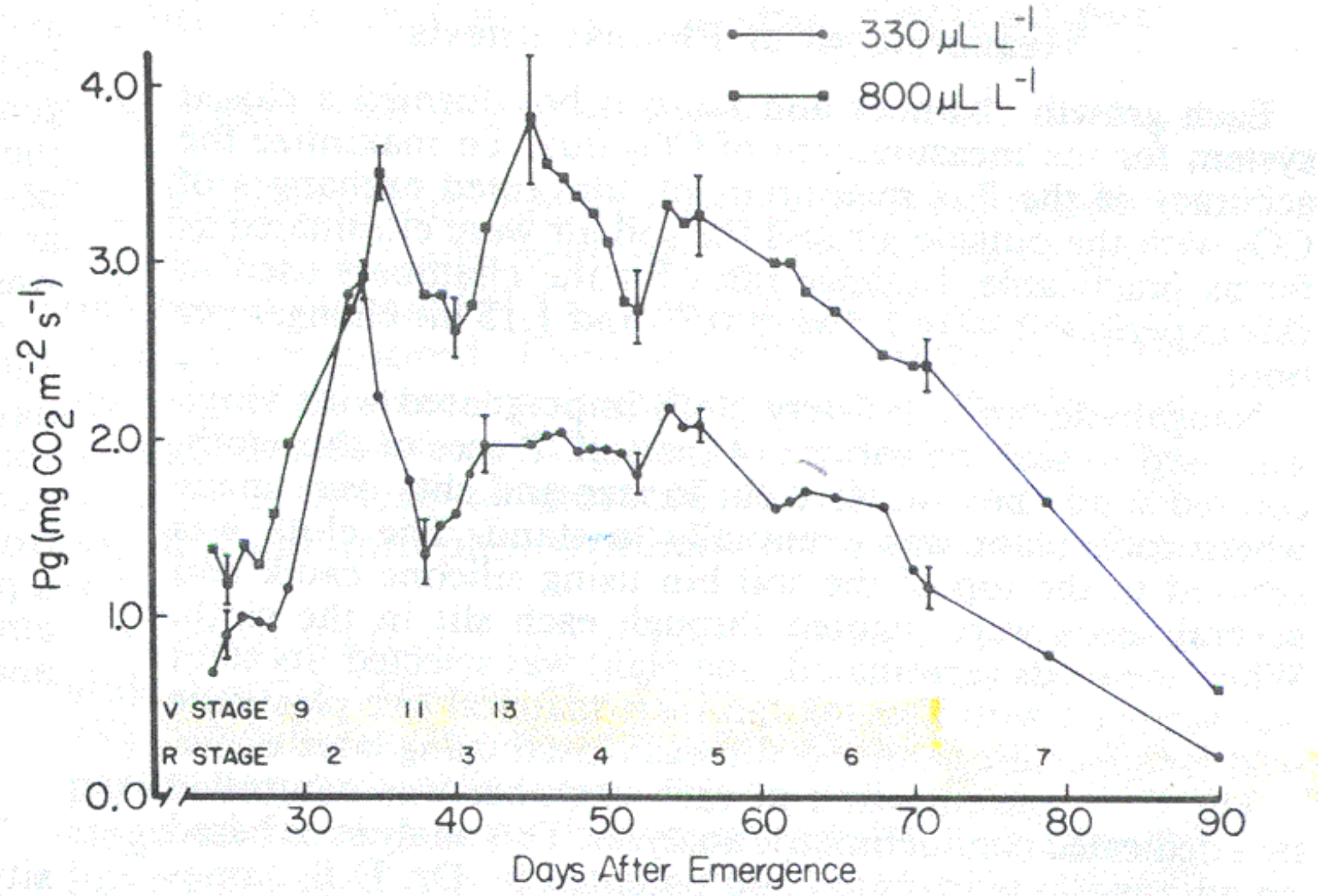


Photosynthesis - Aging

Canopy level – other species - soybean

Canopy Aging and Photosynthesis

Soybean



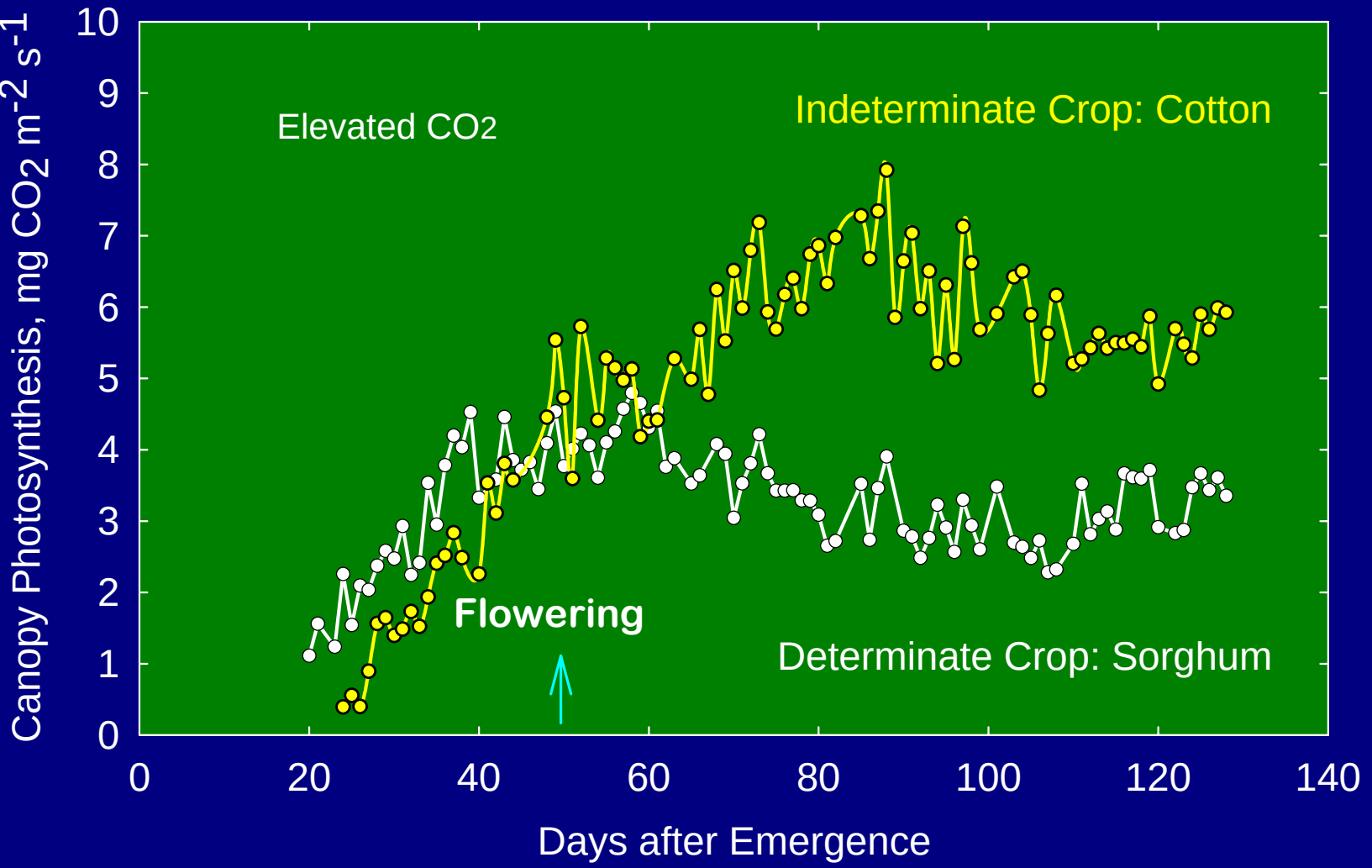
Photosynthesis - Aging

Canopy level – other species

Indeterminate vs. determinate plant types

Canopy Aging - Photosynthesis

Species or Plant type Variation



Canopy Aging and Photosynthesis

- Aging process at the canopy level appears to be a function of leaf-level processes, but modulated by nutrient supply/demand which in turn affects growth and development of various organs including the younger and more efficient leaves produced at the top of the canopy.
- Sustained photosynthetic efficiency and capacity of canopies require optimum environmental conditions (water, nutrients, including carbon), to continually initiate new leaves.
- Any management or environmental factor that limits photosynthesis capacity and efficiency can potentially limit crop yield.