# COTTON PHYSIOLOGY AS AFFECTED BY LEAF AND CANOPY AGING

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**Abstract**

The analysis of patterns of leaf and canopy photosynthesis in relation to crop development will provide essential information to understand carbon partitioning and development of the yield. Studies attempting to determine these physiological parameters in field-grown plants are often confounded because environmental and management variables co-limit growth and photosynthetic processes.

The objective of this study was to determine canopy and leaf photosynthesis and related physiological parameters under controlled environmental conditions as a function of leaf and canopy aging. Experiment 1 was conducted to determine leaf photosynthesis and related physiological processes when plants were grown under optimal temperature (30/22˚C), water and nutrient conditions. Experiment 2 was designed to understand the limitations of canopy photosynthesis under nitrogen-sufficient and nitrogen-deficient conditions when plants were grown under optimal temperature and water conditions. Experiment 3 was designed to understand the limitations of diurnally and seasonally varying temperatures and different levels of carbon nutrition on canopy photosynthesis when water and other nutrients were provided adequately.

**Experiment 1**

Upland cotton (NuCOTN 33B) was seeded 16 May 1999 in 1-m deep soil bins of temperature-controlled plant growth chambers in a nearly natural environment . Each Soil-Plant-Atmosphere-Research (SPAR) chamber was filled with fine sand, and seeds were placed 10 cm apart in three 66-cm rows. Throughout the experiment, the temperature in the chambers was maintained at 30/22˚C, day/night, and the plants were grown in 360 ppm carbon dioxide. A computer-controlled timing device applied a half-strength Hoagland's nutrient solution to each row of plants via a drip irrigation system. Leaf photosynthetic measurements were measured from the 3, 6, 9, 12 and 15$^{th}$ leaves on the mainstem during the boll developmental period (first and second week of flowering) using the LI-6400 portable photosynthesis system. After these measurements, leaf samples were collected for leaf N, chlorophyll, carotenoids, starch, and soluble sugar concentrations. Also, leaves on the mainstem were tagged at leaf unfolding to determine leaf age.

**Experiment 2**

In experiment 2, the same cotton variety was seeded 6 May 1998. Growing conditions were the same as in Experiment 1. At initial flowering, 53 days after emergence, the units were leached with water, and one set was supplied nutrients with no nitrogen while the other set was supplied with a complete Hoagland's nutrient solution. During the experimental period, canopy photosynthesis was measured by a mass balance approach. From the photosynthetic light response curves, canopy light utilization efficiency (LUE) and canopy conductance were estimated each day in both treatments. At weekly intervals, topmost fully expanded leaves were used to determine leaf N by Micro-Kjeldahl digestion. Also, dates of squaring, flowering and first open bolls were recorded.

**Experiment 3**

This experiment was seeded 6 June 1995 in the SPAR units. Fifty percent of seedlings had emerged after four days in both treatments. Temperature was controlled based on the 1995 Mississippi State, Mississippi ambient outdoor temperatures. Seasonal and diurnal differences were maintained within ± 0.1˚C. Plants were grown at either current (360 ppm) or twice-ambient atmospheric carbon dioxide concentrations. The final harvest occurred in each SPAR unit when 50% of the bolls were opened. Nutrients and water were supplied three times per day in sufficient quantities to more than meet the plant requirements with excess allowed to drain. The rooting medium was fine sand as in Experiment 1. Canopy photosynthesis was measured as described in Experiment 2. The dates of flowering and first open bolls were also recorded.

## 1. Leaf Aging and Photosynthetic Processes

Photosynthetic light responses and activity gradually declined with leaf age. The decline in photosynthesis might be due to decreases in LUE and stomatal conductance. Stomatal conductance and LUE showed a trend similar to that of maximum photosynthesis with leaf age. Changes in leaf pigments (chlorophyll and carotenoids) and leaf nitrogen (data not shown) also partially contributed to this photosynthetic decline as their levels started to decline from 35 days after leaf unfolding. Also, levels of starch and sugars decreased as leaves aged (data not shown) suggesting a loss of photosynthetic activity. Therefore any factor that accelerates this aging process should impact canopy carbon gain and finally yield.

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## 2. Canopy Aging and Photosynthesis

Canopy carbon fixation rates were closely related to the solar radiation level at the top of the canopy. Therefore, under favorable nutrient and water conditions, canopy photosynthesis gradually approached light saturation similar to the light response of 20-day-old individual leaves. The canopy photosynthetic rates at 1200 PPFD, estimated from light response curves, increased with the season up to the flowering period and sustained at the same levels during the rest of the growing season when growing conditions were optimum (optimal temperatures, 30/22˚C, and optimal water and nutrient conditions). These trends are different from those observed in field-grown plants in which photosynthetic rates declined soon after flowering. When nitrogen was withdrawn from the nutrient solution from flowering onwards, the canopy photosynthetic capacity declined during most of the boll-filling period . This decline might be due to lower canopy conductance and less effective leaf area caused by lower nitrogen in the nitrogen-deficient environment.

When cotton was grown under ambient temperature conditions, but with optimal water and nutrient supply, the maximal canopy photosynthetic capacity was reached soon after flowering and then decreased as the season progressed for plants grown under ambient carbon dioxide concentration. The apparent decline in photosynthetic capacity for these plants seems to be associated with canopy aging. As the boll load increases, the leaf development slows and the average age of the light-intercepting leaves on the plant increases. This results in reduced rates of canopy photosynthesis. By growing plants in twice-ambient concentrations of atmospheric carbon dioxide, the photosynthetic rate did not decrease as the canopy aged . Both vegetative and fruiting branches continued to grow, and produced 30% more new nodes and leaves on plants grown under elevated as compared to ambient carbon dioxide levels. This indicates that in elevated carbon dioxide more carbohydrates were available to support new leaf growth. Because younger leaves are more efficient, the photosynthetic capacities of high-$CO_2$ grown plants were maintained throughout the season.

The loss of photosynthetic efficiency as individual leaves age is related more to reductions in leaf conductance and light utilization efficiency than to reductions in leaf N, chlorophyll, and carotenoid concentrations. While the aging process of canopy photosynthesis appears to be a function of leaf-level processes, the expected decline in photosynthesis is not observed because there is a younger population of leaves in the upper part of the canopy. Sustained photosynthetic efficiency of canopies requires optimum water and nutrients, including carbon, to maintain this population of younger leaves.